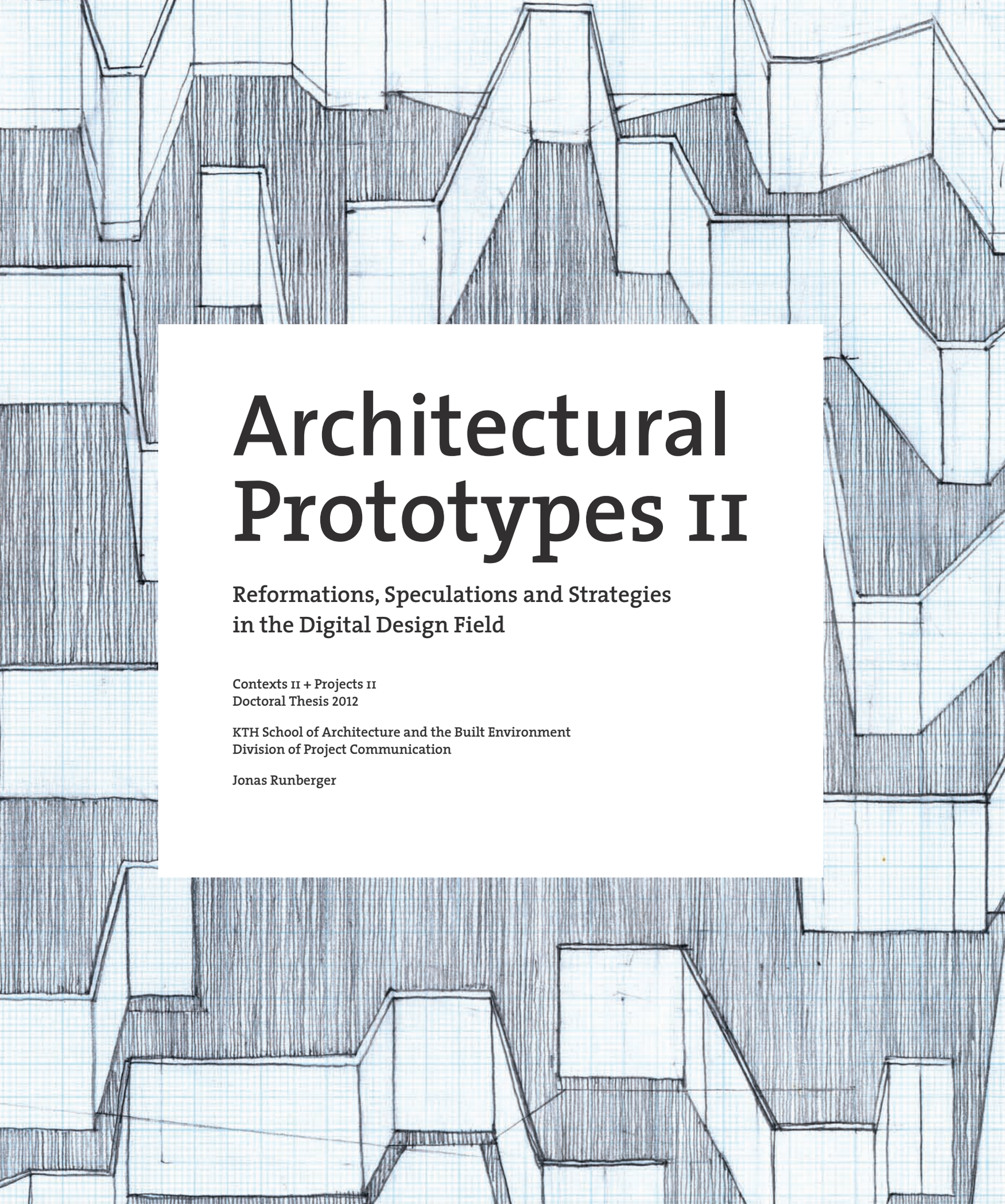

Architectural Prototypes II

Reformations, Speculations and Strategies in the Digital Design Field

Contexts II + Projects II
Doctoral Thesis 2012

KTH School of Architecture and the Built Environment
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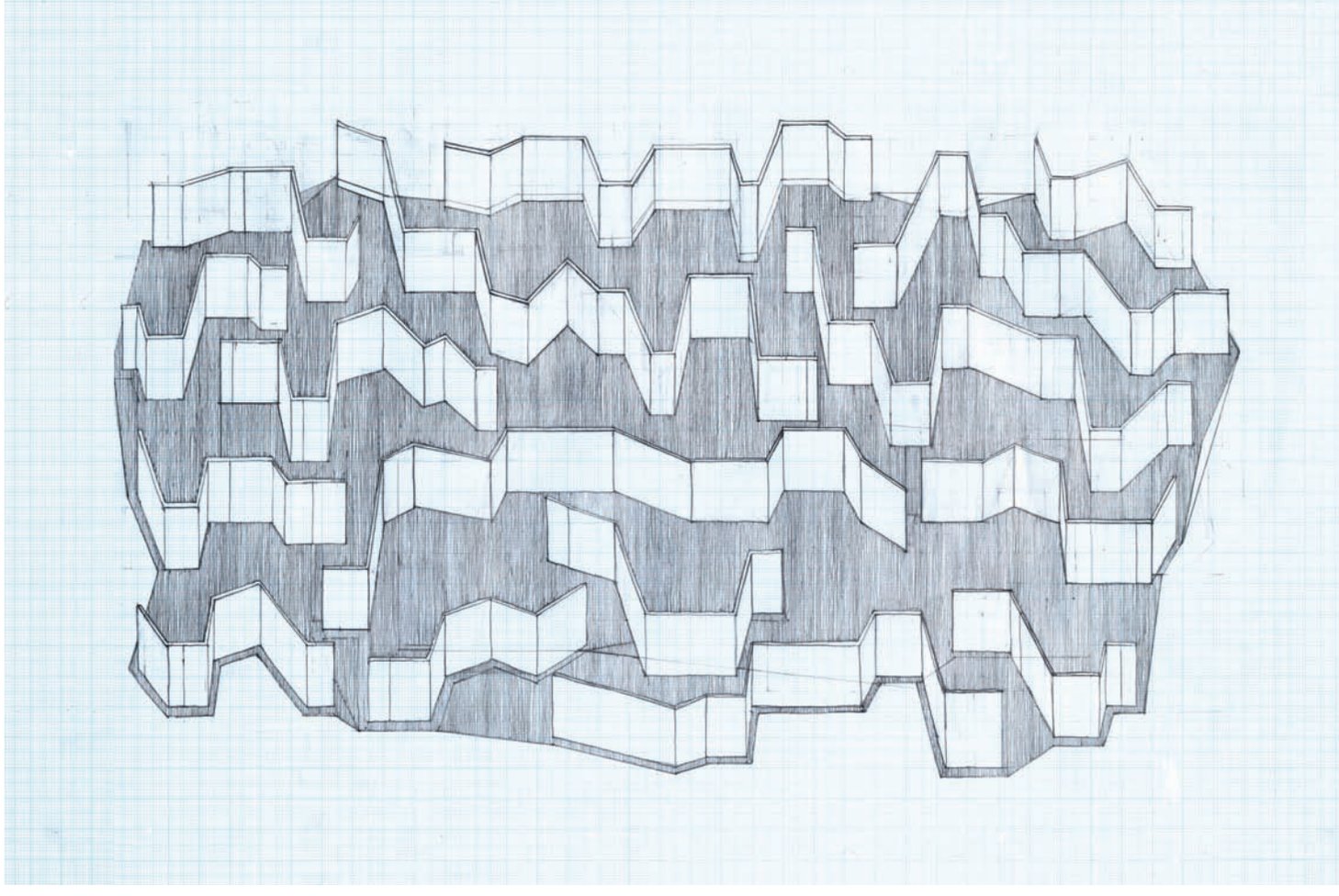

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Secondary advisor: Katja Tollmar Grillner

KTH School of Architecture and the Built Environment | www.abe.kth.se
Division for Project Communication
Royal Institute of Technology
SE100 44 Stockholm
Sweden

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Contexts II

Introductions

> *"Like other media since the Renaissance – in particular, perspective painting, photography, film, and television – new digital media oscillate between immediacy and hypermediacy, between transparency and opacity. This oscillation is the key to understanding how a medium refashions its predecessors and other contemporary media. Although each medium promises to reform its predecessors by offering a more immediate or authentic experience, the promise of reform inevitably leads us to become aware of the new medium as a medium."*

Jay David Bolter and Richard Grusin,
'*Remediation: Understanding New Media*,' 2000 [1]

There may be a question whether the employment of digital design techniques constitutes a profound difference for the nature of architectural design, or if it is simply a mode of design in a new media. To what extent it changes the mode of design practice completely, can be discussed, but the fact that parametric design techniques allow for formal and performative innovation within architecture cannot be dismissed; the past 15 years of experiments have given rise to a diverse design culture in which the deployment of the latest technique becomes an instrument of innovation itself, often undermining the importance of what was in use the year before. The field is now maturing in parallel to the changed conditions in society. Some may argue that expressive formal design was part of an attitude of abundance, and that the development was aimed primarily at the design and production of high profile architecture of the first decade of the 21st century.[2] Others argue that in a time of financial and environmental crises design is more important than ever, and could be applicable in other fields.[3] With new conditions come new roles for design thinking, in particular in the way that constraints may be turned into assets, but this may also require a better understanding of how to manage the resources that can be provided by architectural design.[4]

The aim of this thesis is to give an integrated view of the digital design field within architecture in its different incarnations, and to propose two new areas of future development within the field. In doing this, it builds on previous discussions on the notion of the prototype and suggests that speculative and strategic approaches, that are developed iteratively, are valuable assets in the discourse as practice of digital design. Furthermore, it explores design driven modes of research through a series of architectural design projects to which the author has contributed in different ways. For the purposes of the thesis, the notion of design denotes the collective efforts involved in the processes behind architecture, as opposed to only formal definition or the resulting artifact. It does include these aspects, but also initial conception, analysis, construction and other fields of practice with relevance for the shape, performance and meaning of architecture. Due to this, the notions of design methods and design techniques include both the actual formal conception, and any process that relates to it, in the context of architectural practice. The particular concern regards the role of new digital design techniques as part of the conception of architecture, and how they influence practice and discourses. They are regarded as an important part of the repurposing of the field of architecture, and in this way an analogy to Bolter and Grusin's definitions of immediacy and hypermediacy referred to above can be made. Immediacy denotes a media experience that is immersive as the medium itself becomes invisible, and in hypermediacy the medium is easily recognizable and plays a role in the experience. In their view, media is constantly undergoing reformation, or 'remediation' – the continuous exchange between different media which affects both an older and newer one.[5] As the media of architecture – the multiple modes of representations that are part of the daily practice of architecture, is being remediated through the introduction of constantly evolving digital design tools, it could be expected that there is an exchange between older and newer media. The current status of architectural representation in the discipline is certainly one of oscillation, and as digital and parametric tools enter the practice of architecture, both traditional and new tool set must be evaluated critically. The aspects of the design process to which digital design processes can be applied are still vast, and the notion of what the design process entails differs between different actors within the field. It is important to understand that while many of the projects considered representative of the digital design field may not in themselves perform beyond their immediate spatial concerns and the reputation of their authors or the image of the city or nation, they are also vessels for acquisition of knowledge, in regards to spatial performance, technical execution and team collaboration.

As one response to the urgent issues of today, one might enhance the need to bring the previous era of architectural innovation internal to the digital design field, to a new form of innovation, and to the implementation of new concepts in situations external to the field. This can perhaps be compared to the market approach to innovation, in which the viable implementation of an idea into a market is regarded.[6] This would entail the identifi-

cation of scope (the purpose of new forms of architecture), a further contextualization (how the discourses and techniques of the digital design field can be reformed to include issues external to the field of development), and means (how experimental approaches in the digital design field may be given agency to operate in practice). Herein not suggesting that there is no need for a continued internal development – the current pursuits within areas such as aesthetic discourse are crucial to the understanding of architectural performance at conceptual and experiential levels and the continued exploration of digital fabrication provides the means to construct new formal expressions. The parallel exploration of how this development may inform the overall discipline of architecture, and society in general, is nonetheless an important one.

Architecture does not only respond to issues in society after they have been identified, providing solutions to defined problems. The architect must also look for potential new venues and purposes for architecture through experimental and conceptual work. This has been a primary mode of operation within the digital design field for the past decades, a context in which new technological assets are explored in terms of their potential for spatial design and aesthetic effect. Today, this development is approaching issues external to the field in different ways, and this thesis suggests that there are multiple forms of reformations underway. If digital technology initially has been an enabler and motivator for new ideas in regards to architectural design, many practitioners are now regarding this technology as a natural means for development and no longer the argument for change. In the chapter 'Reformations,' this thesis provides an overview of the role of digital technology to support architectural design related to the role of tools through history and different modes of enquiry that have emerged in the past decade. Beyond current practice, the thesis also proposes two areas in which the digital design field could be explored further. The 'Informed Speculations' chapter suggests that there is a relation between speculative practices of the past and potential future endeavors within the digital design field, and explores a number of concepts derived from Science Fiction Studies and their potential use for a continued speculative mode of digital design within architecture. The 'Strategic Implementations' chapter suggests that new digital design techniques may require a change in architectural practice, and seeks to outline a strategic framework for how this could be facilitated.

Reading Instructions

The doctoral project consists of the research conducted over two dissertations; the licentiate thesis presented at the KTH School of Architecutre in 2008, and the material contained in this book. The extended thesis therefore encompasses three books; the two associated books of the licentiate thesis – Contexts I and Projects I, and the new Architectural Prototypes II book, which is divided into two main sections – Contexts II and Projects II. The distribution of material in the previous associated books and the two sections of the new book follows the same model. The Contexts book / section include the discussions and conclusions of the thesis, as well as important references. The Projects book / section include in-depth projects' descriptions.

The thesis depends on all books, and the design project documentation in Projects I and II constitute important design research processes that are communicated through the projects themselves with supporting text. This approach was introduced in the licentiate books, where the relation between the projects developed as part of the thesis and the discussions and arguments in the Context I book were loosely affiliated through textual links. In the doctoral thesis, this relation is made explicit primarily through extended project discussions in several places in the three main chapters of the Contexts II section. The intention in the licentiate thesis was that each book could be read separately, but also cross-referenced, which was further enabled through the physical design of the two books within one cover. The two new sections are meant to be read in a similar fashion, but are designed as one complete volume. The licentiate thesis books are used for reference to some extent (Contexts I) and two design projects presented in the licentiate thesis are frequently referred to.[7]

The textual links in the Projects II and Contexts II sections can refer to all other sections. Here, links are including the name of the book, followed by a page number, all in square brackets, as per the following examples: Projects I page 45 [Projects I: p.45], Contexts I page 34 [Contexts I: p.34], Projects II page 125 [Projects II: p.125], Contexts II page 86 [Contexts I: p.86]. Multiple pages appear in the following manners; Projects II page 125 to 127 [Projects II: pp.125–127], Projects II page 125 and 127 [Projects II: p.125, p.127]. Single links can also refer to multiple books, presented within the same square bracket in this way: [Projects I: p.52 | Contexts I: p.48 | Projects II: p.126]. In some cases images in Projects I and Projects II are referred to, by page number and image number as follows: Projects I page 69, image 12 [Projects I: p.69 > img.12]. A similar reference system was introduced in the licentiate thesis, and for obvious reasons, links in any of those books refer to the licentiate thesis books only. The typographical principle for the licentiate thesis is presented in both books (these are actual links, not examples) [Contexts I: p.08] and [Projects I: p.06].

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1 Bolter, Jay David & Grusin, Richard, *Remediation: Understanding New Media*, The MIT Press, 2000, p.19

2 See for example: Ouroussoff, Nicolai, 'It Was Fun Till the Money Ran Out,' in: *New York Times*, December 2008, New York Edition, p. AR27 http://www.nytimes.com/2008/12/21/arts/design/21ouro.html (14/4 2012)

3 Michael Speaks has identified tendencies of a shift among architectural critics that previously were promoting high profile design projects, and now argue for a more pragmatic approach to problem solving. Speaks suggests that the new modes of design can be re-applied in contexts of need, but can also benefit from knowledge gained during recent years.
Lecture at KTH February 2011, similar presentation also made here: Speaks, Michael, at: Austin E. Knowlton School of Architecture, given 24/2 2010. Available on-line at: http://knowlton.osu.edu/event/michael-speaks-university-kentucky-0 (14/4 2012)

4 Thomas R. Fisher argues that in a new global situation of organic flows, traditional structures break down, which allows new opportunities for design, but also requires that the structure of practice itself is re-designed; hence the need for managerial skills to be applied within the architectural design field.
Fisher, Thomas R., *In the Scheme of Things: Alternative Thinking on the Practice of Architecture*, University of Minnesota Press, 2000

5 Bolter, Jay David & Grusin, Richard, *Remediation: Understanding New Media*, The MIT Press, 2000, pp.44–50

6 Innovation is often defined as the viable implementation of ideas into reality, as opposed to invention, which can be the creation of something new in itself. http://en.wikipedia.org/wiki/Innovation (22/5 2011)

7 Both books of the licentiate thesis are available online at the following link: www.runberger.net/architecturalprototypes (12/4 2012)

Trajectories within Digital Design

The development in the field of digital design in architecture is diverse, and follows different trajectories. While many concepts are related, the drives for development are often different, and when trajectories coincide, seemingly similar approaches may be motivated in very different ways [Contexts I: p.29]. For the purposes of the initial arguments of the doctoral thesis, three such trajectories are identified.

The integration of CAD into construction workflow has been driven by the potential to describe all parts of a building in a more intelligent way, and to take production considerations into the design process [Contexts I: p.20]. What we may know as BIM – Building Information Modeling, is related to tools within product development, where Product Data Management (PDM) has been an important prerequisite for increased productivity and quality control. In architecture this development was initiated during the 1980s, and already the early CAD-systems often had an object based approach. The overall objective in this trajectory is to control the flow of information in a more rational way, to improve efficient communication and facilitate a change of the overall construction process. Different approaches to BIM are more or less present in all practices today.

Another important trajectory that emerged in the 1990s regards an interest in exploring the potential of new technology to architectural form. The so called paperless studio at Columbia University [Contexts I: p.14] was an important initiating factor, but today this field is global, and includes a variety of approaches. A common ground is an interest in contemporary expressions in architecture partly based on technologies for design support and fabrication. Concepts such as parametric design, associative modeling, and performance are key to this trajectory, where design result is considered as important as the processes themselves. Recently the focus has shifted to a focus on fabrication, including different modes of CNC-fabrication.

A third trajectory may be defined as an interest in computational processes, and the way they can change our way to analyze, generate and produce architecture. The origins can be traced to cybernetics, the discipline of communication and control systems, which entered the field of architecture in the 1960s. Over the years the main interest has been on analytical, formal or structural issues, and today there is a big potential in the way conceptually sound computational models can lead to alternate processes in which even qualitative data can be measures.

There has been a divide between these different paths of development, but there are also attempts to align them.[8] A dichotomy between these trajectories and the important causes for contemporary architecture, risks the dismissal of lessons learned.

Thesis Objectives

This thesis operates in the context of the digital design field, and the trajectories suggested above are considered to different extents in the chapters to come, but more importantly certain traits within the field are identified as a basis for the arguments put forward. There is no way to discuss digital design without acknowledging the importance of the successful implementation of data management systems in practice, such as BIM, but this particular trajectory is often divided from discourses on architecture. This is considered by the author to be a serious limitation. An important objective within the thesis is to suggest that digital design processes, data management and a prototypical approach to development must be related to the discourses of architecture, and the concepts that drive design. This can also be reversed, to say that the discourses of architecture are dependent on the technologies employed within the design process. Furthermore, the research conducted during the preparation of this thesis has a strong relation to design work, and employs a series of design projects as essential empiric material. This associates the thesis with the field of research-by-design. The particular subject matter of the thesis is the future potential of the digital design field of architecture, and the current status of this field is explored and discussed at length. The affiliation with the field of research-by-design is also extended into the research question of the thesis. An ongoing reformation of the digital design field is identified in the next chapter, and rather than providing a straight forward question in regards to the immediate future of the field, the scope of the thesis is to propose two additional areas for further development of the digital design field. The research question becomes propositional, in analogy of the research-by-design mode of the overall thesis, and could be phrased as follows:

What relevant trajectories for future development within the digital design field beyond the already present ones could be considered, and in what way could frameworks for further development be constituted?

This is pursued in a number of ways. The overview of discourses present within the digital design field suggests a current reformation, in which the potentials of the field are repurposed. The thesis proposes two additional areas for this reformation; a speculative approach and a strategic approach. The design driven approach of the thesis is present through the way that the included design projects are used to discuss the nature of the field in terms of techniques and design outcome, as well as a basis for the arguments in regards to the two alternate areas.

In order to understand how digital design technologies can be linked to an architectural agenda, the shifting field of experimental practice, in lack of another definition, is interesting in the sense that it often combines advanced design supported by digital technologies with conceptual formulation that continuously builds discourse. The ‘Reformations’ chapter introduces the idea that the digital design field already is in a state of reformation and a number of aspects deemed of particular relevance for continued discussions. In the ‘Techniques and Processes’ section, the characteristics of the methods and design techniques within the digital design field are discussed through references as well as design projects. ‘Concepts and Discourses’ brings forward a number of crucial concepts associated with the digital design field, and the different discourses that are related to the field, again with investigations on how these concepts can be traced among the design projects featured in the thesis. ‘Practice and

Discipline' concludes this discussion, and in addition to the already present perspectives that reform the field, the two new approaches, or research areas, are identified. The speculative approach is proposed to support the continued experimentation within the field in parallel to the current focus to implement digital design within professional practice. This is not to say that the digital design field is lacking in experimental modes of design, but suggests a framework for how such speculative work can be contextualized in a wider situation. The strategic approach is proposed in order to bring the implementation of digital design methodologies to another strategic level, beyond current focus on formal issues and techniques for design and fabrication. It is primarily directed towards current initiatives that introduce findings from an experimental scene to be implemented in commercial practice.

There lies potential in the intersection between the more experimental modes of practice and what sometimes is referred to as mainstream practice. The long term speculation that may provide scenarios for future modes of operation within the practice and spatial performance of architecture, and the implementation and continued investigation of new techniques in daily practice may provide ideas about the agency of the digital design field. This entails both purpose/objective and the means of reaching these, but not only in direct response to issues that we can identify today, but also through speculations that prepare us for future unknown scenarios. In the 'Informed Speculations' chapter, terminology and theories within the literary field of science fiction are suggested to be useful in the formation of a framework for speculative experiments within the digital design field. The section entitled 'Architectural Experimentation' presents three historical references, and relevant principles for their modes of practice. 'Studies on Speculation' introduces a number of concepts and themes from the field of science fiction studies, as well as six works of fictions in which these can be traced. 'Spatial Speculations' discusses a number of recent examples of speculative fiction associated to architecture, and formulates how this could be further pursued. The final section 'Speculations in the Digital design Field' suggests three areas in which such a mode of speculative design are regarded fruitful.

There is also opportunity for innovation in the deployment of digital design into daily practice of architecture, for the benefit of the discourse and the outcome of architecture alike. A pragmatic contextualization, informed by the issues present today, is a challenge to the field – how can the often time consuming processes of development of digital design techniques for custom purpose in projects continue in practice, and become viable when exposed to the conditions within commercial practice? How can modes of development and execution be intertwined in a way that allows practice to benefit from new design thinking, and how can the continued development within the digital design field be challenged in a constructive way by these issues? The 'Strategic Implementations' chapter introduces a model for strategic thinking in the deployment of digital design techniques within architectural practice. In the 'Strategic Thinking and Digital Design' section, important references from the fields of strategic organization and management as well as precedence in parametric design are presented. 'Digital Design Strategies' proposes the idea of comprehensive strategies for digital design implementation, explored through the design projects included in the thesis.

The 'Reflections' chapter concludes the Contexts II section, and here the two new approaches are related and discussed, in the purpose of identifying synergies and oppositions between them. In this chapter the overall mode of research is also discussed, in particular in regards to the format used in the thesis, and future opportunities for further research are suggested.

Sources and Modes of Research

The different contexts explored by the author have been important for the formulation of the two research areas presented in the doctoral thesis. There is a divide between experimental design in education and implemented methodology in practice; both contexts face the challenge of making relevant assumptions about near future practice, but under very different conditions. A student may be well equipped to employ various digital design tools in order to explore new ideas of architectural form, but may not regard his or her work as part of a continuous research within education and instead limit the ambitions to produce proof of value for future employment. The practitioner may face similar limitations due to expectations of client or contractor interests. The Informed Speculations chapter is in this sense intended as an addition to current discourse within the field as a response to the combined experience of the experimental design and teaching environments in the USand the UK, and as a proposal for a continued discussion on future potentials, which is crucial for an industry known to avoid risk taking.[9] The Strategic Implementation is intended to contribute to the field by complementing the strong bias towards working with fabrication methods in academia and BIM-supported workflows in practice, and a way to understand the further ramifications of how new digital design methodology may affect future practice.

The thesis combines a design driven mode of research with an understanding of the discourses that relate to the field of digital design, in the ambition to make several contributions. The modes of research explored may hopefully serve as reference for future research-by-design approaches, in particular in regards to the relation between design projects and the arguments made. The proposal of two new areas of future research is regarded to be of particular relevance for the digital design field, in respect to future practice and research alike. The emerging field of research-by-design is continuing to evolve, and within architecture it is certainly not exclusive to the digital design field. In his seminal work from 1969, Herbert A. Simon opposed science of design to the natural sciences, in that it is focused on how things ought

8 See for instance: *Architectural Design, Closing the Gap: Information Models in Contemporary Design Practice*, vol. 79 Issue 2, Wiley, 2009

9 The author had the opportunity to spend 2 months in Los Angeles as an independent researcher in the spring of 2007, attending seminars and student reviews at SCIArc and UCLA. Teaching experience at the Architectural Association and the London Metropolitan University, as well as exchanges between the KTH School of Architecture and schools and practices in London have provided an understanding of the London context.

to be rather than how they are. He showed that there already existed parts of a theory of design, and suggested a number of topics relevant to the sciences of the artificial. Several of them resonate with themes present within the digital design field, such as theories of evaluation, computational methods, formal logics of design and the search for alternatives.[10] A later contribution and frequent reference is the idea of knowledge production in a new mode; Mode 2, introduced by Michael Gibbons and others, in which the context of knowledge production as well as the type of knowledge is crucial.[11] Discoveries within Mode 2 are made in the broader, transdisciplinary social and economic contexts of practice, and the knowledge produced is meant to be applicable within that context. Among several key aspects for the dynamic characteristics of Mode 2, knowledge through design and computational modeling again relates to the particular approaches discussed within this thesis.

While these sources only rarely directly discuss the particular traits of the discipline of architecture, they have been subject to inclusion from different ends. Fredrik Nilsson suggests that discovery and application cannot be separated within Mode 2, and relates to the "minor" or "nomadic" sciences of Gilles Deleuze and Felix Guattri, as well as the "major" and "minor" professions of Donald Schön, as he suggests that "the tools and thinking of architectural practice" can be employed in order to explore, discuss and produce knowledge about societal conditions and realities.[12] Together with Halina Dunin-Woyseth he argues that "architectural practice moves in the area where creative practice and transdisciplinarity overlap," and transdisciplinarity here denotes research which "is at once between the disciplines, across the different disciplines, and beyond all disciplines."[13]

The design driven mode of research employed in this thesis is related to 'artistic research,' a field that has been growing since the mid 1990s. It has been defined as both autonomous (within its own practice) and complementary (to other sciences), with a capacity "to act in an explorative and innovative manner through material forms". The research methods within this field are often action-oriented and performative in the sense that material produced through artistic production is used to produce knowledge and reveal latent concepts. As an extension of artistic practice, it combines intuitive forms of understanding, systematized artistic work and critical reflection.[14] This field is wide however, and the subject matter of this thesis, while sharing conditions such as the inquiring and explorative nature of the artistic research experiment, narrows down the objective through the association to the digital design field. As will discussed in the 'Reformations' chapter, the digital design field within architecture constitutes its own sphere of interests. The ambition here is to employ design projects through an understanding of employed digital design techniques as well as design outcome to formulate new directions within the digital design field, and propose specific frameworks for a continued development. This is a continuation of the work presented in the previous and associated licentiate thesis, in which the author employed several design projects with personal engagement as sources for investigation. In the doctoral thesis there are primarily two modes of engagement in the design projects included. Seven of the included projects were developed by students in studios coordinated and taught by the author. Five projects were developed by the author through collaborations in practice and academia.

In the case of the student projects, the contributions of the author include the definition of an overall agenda, the introduction to digital design methodology, and the continuous discussion during the progression of the projects through tutorials and reviews.[15] The use of the design studio in education as part of a research agenda is not without precedence. Among the most well-known is the Harvard Project on the City, led by Rem Koolhaas from 1996 to 2000, with a commitment to research as a prelude to design.[16] There, the focus lies on research conducted by students, through processes of information gathering, analysis and synthesis similar to the early phases of design, with an ambition to disseminate key findings.[17] This approach can perhaps make the findings more easily be identified as research, but there are also examples when design lie at the core. The Design Research Laboratory (AA DRL) at the Architectural Association in London was initiated in 1997 (following the previous AAGradDes program), as one of very few Masters Programs that offer a team based Masters Degree. The objective is to deploy design as a mode of research, based on open experimentation with a foundation in new design and fabrication technologies. The collaborative mode is an important factor, facilitated through individual student work in collective forms of project negotiation, exchange and peer-to-peer learning.[18] Similar approaches can be found also outside of the digital design field. Based on his work at the ETH School of Architecture, Marc Angélil suggests that the teaching of architecture should "trace the boundaries between what is perceived to be of the discipline and what is outside of its territories", which entails that one is operating on grounds that are not secure. According to Angélil, design as a form of research involves experimentation, and requires a type of enquiry, a search, or research, in which hypotheses are tested, rejected, and reformulated. Experimentation in this sense takes on the role of an operational strategy, and a process orientated disposition of architecture is stressed. He uses the term praxis for the specific processes involved, in three different modes.' Technical praxis' involves the 'how' of design, and the methods and instruments deployed in design. 'Intellectual praxis' is based on the notion that architecture constitutes a form of discourse with theoretical investigations being an integral part of design. An understanding of design is promoted as a strategy for the production of thought, and an awareness of the intellectual and cultural contexts of the work must be established. 'Intuitive praxis' suggests that 'intuition' as a form of practice accelerates investigation due to its immediacy and directness, and combined with associative thinking promotes invention.[19]

The educational environments in which the design projects of the thesis were developed relate to these issues, especially in regards to open experimentation, collaborative work (in the case of the KTH), and parallel activities of research and design practice. While these environments to some extent claimed a research approach as part of the curriculum, the primary focus was on design, and an explorative mindset to how digital design techniques could affect architectural practice.

They shared a common ground in the digital design field, as well as in a prototypical approach to design in which projects are developed in stages over a full year. Each studio also had its own overarching agenda [Projects II: p.77]. In Diploma Unit 16 at the Architectural Association, the exploration of architecture as a mitigating factor in extreme environments set the conditions for the student work, and the project commenced over the full academic year.[20] In Studio 11 at the KTH School of Architecture, branded as 'Architectures of Interdisciplinarity,' methods for collaboration, especially between architects and engineers were important assets, but the theme of the year also involved an architectural task deemed of particular societal interest – the Energy from Waste power plant.[21] In both of these approaches, the projects have not been developed purely with the objectives of this thesis in mind. They have been orchestrated in a way to enable relevant information to be extracted, but they also serve other purposes (the education of a student or the fulfillment of project requirements).

The projects developed in commercial practice, as part of the author's position as director of Dsearch, an environment for digital design development within White Arkitekter AB.[22] These projects are either developed directly by the author as contributions to larger architectural projects within the office, coordinated by the author in similar situations, or developed as prototypes for future deployment within the office. There are a number of examples on similar environments within architectural practices as well as engineering firms, and these are presented as part of the 'Reformations' chapter [Contexts II: p.44]. An important condition is the way new digital design techniques here need to be integrated in overall workflows, and the mode of operation of Dsearch at the time of the conclusion of this thesis is still in formation. The projects included should primarily be regarded as first stage prototypes, upon which a discussion of future development could be conducted. This relates them to the two projects presented in the licentiate thesis, and frequently referred to in the doctoral thesis – projects developed in an academic setting within the Krets research group.

The conditions for the educational studios were to enable an experimental form of design and of studies, in which the student was given a loose framework of ideas and resources, to form his or her project. 'Real' project conditions have been 'simulated' toa certain extent, but the teaching environment, especially one that emphasizes an experimental approach, is regardless a constructed situation which is both enabling (in the allowance of risk taking) and limiting (in the reliance on hypothetical purpose). As an example, the requirements of the Studio 11 briefs in regards to visitors' centers and public additions to programs were formed by the teaching team as a potential contribution to future energy from waste plants, but also to provide students with a challenging exercise in a context relevant to society. When representatives from professional practice were met, other views were presented, and the speculative design proposals did not necessarily provide answers to the questions regarded as most crucial to the operators of such facilities. The projects developed as part of Dsearch are all related to larger projects developed within White Arkitekter AB. Their purpose is however not only to resolve issues arising in 'real projects,' they are also formed as part of the long term development within the firm, and as cases that may open up future opportunities. This approach, which requires the investment of internal resources, allows certain potential solutions to be developed beyond the intentions of the individual project, which (for the purposes of White as a practice) allows the creation of repositories or archives of methods as well as formal approaches. The objective from the perspective of White as an organization is that Dsearch should bring a competitive edge in regards to practice related issues. At the current stage, this is yet to be fully proven, but the findings so far provide material that is relevant to include in the doctoral thesis.[23] The direct relation to opportunities given within the practice has to a certain extent limited the exploration of the full potential of particular design engagements, due to changed agendas within the general design team, issues related to tendering processes or simply delays in the progress of the overall project. This is an issue for design

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10 Simon, Herbert A., *The Sciences of the Artificial*, Second edition, The MIT Press, 1981

11 Gibbons, Michael, et.al., *New Production of Knowledge: Dynamics of Science and Research in Contemporary Societies*, Sage Publications, 1994

12 Nilsson, Fredrik, 'Transdisciplinarity and Architectural Design: On Knowledge Production through the Practice of Architecture,' in: Dunin-Woyseth & Nielsen, *Discussing Transdisciplinarity; Making Professionals and the new Mode of Knowledge Production*, AHO, 2004

13 Dunin-Woyseth & Nilsson, 'Some Notes on Practice-Based architectural design research: Four 'Arrows' of knowledge,' in *Reflections 7*, Sint-Lucas School of Architecture, 2008

14 These definitions of artistic research are based on: Hughes, Dyrssen & Hellström Reimer, 'Artistic Research Today and Tomorrow,' in Lind, Torbjörn (ed.), *Form och färdriktning – Strategiska frågor för den konstnärliga forskningen*, Årsbok KFoU Vetenskapsrådet, 2011

15 While the educational situations in which these student projects were developed employed pedagogical models facilitating learning and exploration of digital design methodology, the ambition here is not to present the work as a result of research into design pedagogy, or a mode of 'research by education.'

16 Koolhaas suggests that architecture need research due to the evolving conditions of its practice in order not to become an increasingly inappropriate activity. Gwerts. Ken, 'GSD's Koolhaas Heads 'Project on the City,' in: *Harvard University Gazette*, June 06, 1996

17 Varnelis, Kazys, 'Is There Research in the Studio?,' in: *Journal of Architectural Education*, Volume 61, Issue 1, September 2007, pp.11–14

18 Steele, Brett, 'The AADRL 1997 – 2007 Or The Death of Models: Notes on the Evolution of the Networked Studio,' in Verebes, Tom et.al., *DRL TEN: A Design Research Compendium*, AA Publications, 2008

19 Angélil, Marc, *INCHOATE – an Experiment in Architectural Education*, Swiss Federal Institute of Technology, Zürich, 2003

20 Diploma level studies at the Architectural Association regard 4th and 5th year students working in parallel. AA DIP 16 was initiated by Jonas Lundberg and Steve Hardy in 2005, and the author was invited to replace Hardy by invitation from Lundberg. The team of main tutors 2008 – 2010 included Jonas Lundberg, Jonas Runberger and Andrew Yau, and continues still under Lundberg and Yau. The position as AA DIP 16 Unit Master was also supported by KTH Project Communication, and the author's role was dual – as tutor and as researcher. [Projects II: p.94]

21 The studio system at the KTH School of Architecture resembles the unit system of the AA, with 4th and 5th year students working together during the fall. In the two spring semesters the 5th year students focus on their diploma thesis. The Architectures of Interdisciplinarity design studio was initiated by Hanif Kara, Lina Martinsson, Jonas Runberger and Paul Scott, with support from Reuben Brambleby, Raimo Joss and Alexander Trimboli. Sander Schuur joined the teaching team in the spring. [Projects II: p.94]

22 Dsearch was formed in the fall of 2010, as a digital design development environment within White Arkitekter AB. Dsearch is formally a part of the IT Methodology division, but also operates directly in design processes and has a strong affiliation to 'Kunskapsbygget,' the internal R&D division of the same practice. The name Dsearch primarily alludes to 'design search'; the iterative design development supported by digital techniques and methods, but also to 'digital design research, a broad term indicating the employment of digital tools with a direct relation to the inner workings of the architectural design process. [Projects II: p.94]

23 Beyond the projects presented in the thesis, Dsearch has since its foundation been involved in 15 projects ranging from very limited engagements to development influencing overall design, and one winning competition entry.

research conducted in direct affiliation with commercial practice, but the objective to use the design development in order to better understand the conditions on which such development depends still makes the outcome relevant for the purposes of the thesis. In relation to Mode 2, the objective has been to gain knowledge about the design and management of digital design within commercial practice, and to attempt to propose a framework for how this could be facilitated.

It is however important to note that, while one can argue that there is a research-by-design approach as part of the design process of the featured projects, the claim to make them into empiric research material is based on the way they are being revisited within the doctoral thesis. The design projects are employed as research material in several ways. At a primary level, they have served as experiments that explore techniques, concepts and meth-ods in a way that benefit both their environments (education or practice) and the purposes of the thesis. This was facilitated through the formulation of briefs, and the selection of design techniques employed [Projects II: p.77]. The second level is the integration of process descriptions and design outcome into the thesis. This involves aligning terminology, making a selection among projects, reinterpretation of certain issues in relation to findings and conclusions of the theoretical part of the thesis, and as investigations of issues posited in the Contexts I book. At a third level they also serve as models on which the arguments made in the Contexts book rely. They can in this way be seen as contextual experiments (in education and practice) as well as demonstrators, and by revisiting them they can be associated to lines of reasoning that were not explicitly targeted during the design process. This third level is conducted through sets of 'design project enquiries,' in which the projects have been revisited, and are discussed from several different perspectives. These enquiries are distributed throughout the thesis, and are in this way associated to the different discussions. Four such enquiries have been conducted. The 'Reformations' chapter includes two; the first considers formalized aspects of the digital design techniques used, and the second the architectural performance of the design proposals. The enquiry in the 'Informed Speculations' chapter regards potential speculative aspects of the design projects, in terms of the process as well as the design outcome. In the 'Strategic Implementations' chapter, the enquiry draws on relevant issues from a strategic perspective, and the different levels of operational design strategies suggested in the chapter are applied on the projects. The enquiries are based on the experience of the author, as co-designer or tutor, as well as the project documentation presented in Projects I and Projects II. In this way, they are regarded as an analysis of each project through four different lenses, and a particular design research method developed as part of the thesis. They relate the propositional character of the different chapters to the conditions of the projects, and to some extent verify the arguments put forward. They could not however be regarded as conclusive; the case material provided with the projects is limited, and the nature of design driven research cannot be regarded as providing empirical evidence or truths. The enquiries could also be considered to be a mode of operation for a critical and reflective kind of design practice, in the sense that they explore the internal conditions of the design projects.

In this way, the design projects operate as contextual experiments (in relation to education or practice), as well as demonstrators (that make findings explicit). This direct involvement in the creation of empirical subject matter makes the design driven mode of research related to action research, in the sense that there is a direct involvement in the practice context explored, and that the conclusions drawn may not be possible to generalize without making further experiments in a new context.[24] 'Action Science,' the field of Organizational Development affiliated to action research, as defined by Chris Argyris, is to some extent related, if the particular focus on management and organizational learning were to be realigned with design related issues. The interactions with a practice would need to be replaced with the interactions within a design process, in the development of a set of tasks that relates to practice through its methodology, but that also relates to a wider context through the discourses of digital design.[25] A similar approach can be taken to the action research association; the participatory aspects are inherent to the design process, and research conducted through design processes includes such aspects, but most importantly, the architectural design process involves multiple agendas. The design driven research combines the ambitions of design as a projective activity with a reflective understanding of the implications of design decisions as well as of the inner workings of the process itself. With the added focus on prototypical characteristics as enabled by digital design techniques, this becomes even more relevant. It also sets the research in relation to more technically biased endeavors, such as the focus on data management and standardization of BIM development and the numerous explorations of the formal capacity of digital design thinking in regards to form making and physical fabrication. The previous references to Mode 2 and artistic research are of particular interest in regards to knowledge produced in practice, the arising new specialisms within digital design in practice enable sharing of knowledge between peers through the direct dissemination of code, scripts and parametric definitions on the one hand, but on the other hand depend on ordered structures for design development and transdisciplinary exchanges between general design professionals and specialists. In relation to the three modes of praxis introduced by Angélil, technical and intellectual praxises are potentially intertwined within the digital design field of architecture, in the way that specific techniques often are coupled with aesthetic performance, with an associated discourse. This will be further discussed in the 'Reformations' chapter. Intuitive practice, as defined by Angélil, is a potential limitation to the field. To intuitively operate within the field of digital design requires advanced technical skills specific to this field, and perhaps an intuition which is different from the architect as a generalist. In order to provide the accelerated investigation through immediacy and directness Angélil suggests, there is a need for a better understanding of how digital design techniques can be integrated into general practice. This will be pursued in the 'Strategic Implementations' chapter. Another kind of accelerated investigation may be found within the realm of the speculative, following the tradition of experimental architecture, a subject matter to be discussed in the 'Informed Speculations' chapter.

These are issues for practice and education alike, especially with the rapid development of digital design technologies.[26] The pro-

jects that are part of the thesis were to some extent developed in controlled environments in which the full complexity of these issues could only be touched upon. The local environments in which they were conceived; the design studios within education and the Dsearch development within White Arkitekter AB, have however allowed basic principles to be investigated, in particular in regards to learning and knowledge production as part of design practice. In this respect, the design work, and the subsequent design project enquiries, belong to what Christopher Hight has a media of architecture that does not exist outside of the practice of Architecture. Instead, they become "epiphenomenal platforms" from which architectural practice and thought can be explored, and be part of the formation of "a conceptual armature".[27]

Beyond the project specific considerations, the digital design field is also related to a number of fields with long research traditions. Computer Science is relevant to both technical skills and issues of management in regards to techniques and tools. The aesthetic discourses may seem to belong to critical theory; at least to the extent that architectural design can be a critique on par with other cultural phenomenon. This thesis however introduces two additional fields of study, previously not associated to architecture or the digital design field to a greater extent. The purpose is here to use theoretical frameworks external to design practice, in order to provide grounds for an alternate conversation on the potential future of digital design within architecture. Contribution to research conducted within these external fields has not been a primary focus of the thesis.

In order to develop an argument for the speculative, a study of the field of Science Fiction Studies has been conducted. This is in no way conclusive, and the author has no aspirations of giving a completely objective view of this literary field (this is virtually impossible). Instead, a number of concepts have been appropriated for use in building an argument for future speculative modes of digital design in architecture. The second field belongs to the field of management and strategy. Again, this thesis cannot aspire to the provision of new knowledge within that particular field. The ambition is to provide a valuable contribution to the field of digital design, by considering general and specific approaches to strategic development and management. While there are examples of more strategic planning within the field already, this is often hidden as market assets within successful firms (who may publish their design results, and the digital methods associated with them, but rarely discuss internal processes or the coordination of specialist teams).

The discussions on strategic implementation of digital design methodology may provide useful models for practice and particular approaches in the further development of the digital design field. The proposals for speculative frameworks are developed as a support for future experimentation within the digital design, and as a contribution to the discourses within the field. As a parallel to the exploration through design projects, this entails using written sources that present technical innovation to the field, as well as sources that are part of the production of discourse. In some cases these sources coincide; presentations of new design methodology may be coupled with a discursive mode of writing that may promote the specific methodology. The selection of sources has therefore been critical. Many of the combined discursive/methodological sources have been used in a partial sense; by referring to their technically oriented proposals, and/or relating to particular contributions to discourse. This is in particular relevant to the 'Reformations' chapter. References on digital design methodology are employed to provide an understanding of the characteristics of digital design technologies, but these sources do not emphasize the relation between methodologies and design outcomes. The discussion on Concepts and Discourses gather a number of themes that re-emerge within the digital design discourse, and can relate to geometry, technical performance and/or aesthetic performance that primarily is discursive, but informs the understanding of how digital design influences ambitions and concerns within the discipline of architecture.

The ambition is to inform design processes through strategies and methods available within the field of digital design, through the exploration of developed designs and the processes that created them. The mode of operation and enquiry can be related to several identified research strategies, as defined by Linda Groat and David Wang. They define Simulation and Modeling research as originating in an interest with the replication of real-world realities, and simulation "occurs when a replication of a real-world context (or a hypothesized real-world context) contains within it dynamic interactions that are the result of manipulated factors".[28] Computer models are regarded as a tactical category in itself, and the authors claim that they have blurred the distinction between representation and simulation in practice. They also acknowledge that computational tactics may very well change the way simulations are understood on a strategic level due to technological advances. For experimental research, the possibility for the researcher to "credibly establish a cause-effect relationship", to understand the reasons for particular outcomes, is key.[29] This implies a controlled environment – the laboratory or less-controlled field sites - and a danger of simplifying complex research issues. Case study analysis can be done on single or multiple cases, and the choice between these two tactics affect the outcome. In both cases, the role of theory and research questions involved, as well as replication of outcome is deemed crucial. With a narrowed down research question, a multiple case approach may be preferable, in which the number of cases used becomes an issue.[30] Groat and Wang also suggest that combined research strategies is a way to deal with strengths and weaknesses of the different approaches, and with a reference to John W. Creswell, they describe three general and for architecture suit-

24 Groat, Linda & Wang, David, *Architectural Research Methods*, Wiley, 2002
25 Argyris, Chris, *On Organizational Learning*, 2nd Edition, Blackwell Publishing, 1999, p. 433
26 Gibbons, Michael, et.al., *New Production of Knowledge: Dynamics of Science and Research in Contemporary Societies*, Sage Publications, 1994, p.19 and p.139
27 Hight here proposes that within a design research field of architecture, the media of architecture – drawings, diagrams, modeling and writing, can be understood as means through which issues such as programme, space and agency can be explore. Hight, Christopher, 'One step towards an ecology of design: fields of relations and bodies of knowledge,' in: Hensel, Michael U. (ed.), *Design Innovation for the Built Environment: Research by Design and the Renovation of Practice*, Routledge, 2012
28 Ibid., p.279
29 Ibid., p.254
30 Ibid., p.356

able modes; the two phase approach (combining two or more strategies in sequence), the dominant / less dominant design approach (inserting one type of research design within the framework of a distinctly different one) and the mixed methodology approach (the integration of two or more research strategies). The digital design methods employed in development of the projects can to a certain extent be comparable to research methods. In particular, simulation and the differentiation between models and representation are relevant in most projects; as design tools, and as instruments that provide feedback. The development of parametric systems also provides an understanding, at least local understanding, of the relation between cause and effect, and particular parts of each project, similar to the design loops identified previously, and can be seen as experiments [Projects I: p.07] When particular parametric definitions are re-deployed in alternate projects, further causal understanding is achieved. The parametric systems developed within Dsearch are deployed in several cases, and while they are primarily aimed at providing design solutions, an important part of the development is to make use of these cases in order to provide knowledge in regards to the performance of the systems themselves, as well as what is required at an organizational level. The evaluation of the design projects themselves is to a certain extent case based, with multiple cases, where the differentiation in nature between the projects requires specific evaluation for each case, in which the particular points of interest in relation to the arguments in regards to digital design strategies and tactics, or techniques, are located and evaluated in their context. This has been referred to as an explicative approach, meaning that a holistic approach is necessary.[31]

Research Process

The work with this doctoral thesis was initiated at the KTH School of Architecture in 2005, and with the rapid development of the digital design field, the conditions have during the work changed. With this in mind, the author has been open to opportunities given during the course of research, as part of the research, or as activities external to the thesis. In order to give an understanding of the different contexts that have contributed to the work, an overview of the progress of the thesis follows.

The licentiate thesis that is part of this doctoral thesis was completed and presented in 2008 at the KTH School of Architecture. At that time, an offer to shift research affiliation to the Division of Project Communication[32] at the KTH Department of Industrial Economics and Management (KTH INDEK) provided the opportunity to include aspects of management and organization as applied to architecture and digital design. This entailed a pursuit of a doctorate in Industrial Engineering and Management, with digital design and prototype development in Architecture as a theme. In 2009 the department of Project Communication moved from KTH INDEK to the KTH School of Architecture and the Built Environment (KTH ABE), as a division of the department for Real Estate and Construction Management. At this point the decision was made to again change the subject of the thesis to a doctorate in Architecture, to be conducted at and affiliated with the department of Project Communication. The shift of venue and affiliation of the doctoral project from the School of Architecture to Project Communication was the first and most important change from the approach in the licentiate thesis, and allowed issues of management, organization and communication to be regarded in close relation to the notion of the prototype and the digital design discourse.[33]

The doctoral studies have since 2008 been pursued at part time; the reason for this has primarily been to remain associated with architectural practice, which has been a continuous part-time commitment. The engagement in practice has also provided opportunities to explore issues directly relevant for the thesis, something which has been a condition discussed with practice superiors in those engagements, as well as advisors of the doctoral thesis. The previous employment at Scheiwiller Svensson Arkitektkontor AB, was in January 2009 continued in the new role of director of research & development. This involved coordinating overall method development as part of the board of executives, with the agreement that case projects could be investigated as part of the ongoing thesis. In the spring of 2010 the author was offered a position as director of a recently formed digital laboratory at White Arkitekter AB, and after careful consideration this position was accepted and initiated in August 2010. This shift of employment allowed, and required, a shift of research focus in regards to the practice component. The activities at Scheiwiller Svensson Arkitekter AB involved management issues in regards to R&D at a general level, which has influenced the work with the thesis, but is not present among the project cases. The new engagement at White Arkitekter AB, as director of Dsearch, instead allowed management issues in direct association with the already defined subject matter of the doctoral thesis to be considered.

The activities within Dsearch are present as project cases in the Projects II section, as well as a context for the proposed digital design strategies. The relatively short time in this position has not allowed for these strategies to be fully implemented and fully tested in live projects; this is rather an opportunity for future research. This shift of practice employment and affiliation was the second important change after the completion of the licentiate thesis, allowing the ideas of prototypical approaches and digital design methodology to be directly associated with practice related issues in a Swedish context.[34]

The doctoral project has also been closely linked to a number of teaching situations. The licentiate thesis included summary presentations of student work developed in the two KTH design studios 'Informed Modularity' and 'Architecture InFormation' [Projects I: p.100], co-taught by the author. In the continued work towards the doctoral thesis, the design studio has been given a more important role; as a co-coordinator and co-tutor the author has been able to include aspects important to the doctoral project and combine those with learning requirements. This has allowed the teaching situation to function both as a learning environment and as a laboratory that to certain extents contextualize the design techniques and methodologies as part of overall project goals. During the academic year 2008 – 2009 the author held the position of Unit Master for Diploma Unit 16 at the Architectural Association School of Architecture, London (AA).

During the academic year 2009 – 2010 the author held an uncontracted position in the unit, and was primarily participating in reviews and assessment. The second important educational context involved the initiation and execution of a new design studio as part of the Master level studies (4th and 5th year) at the KTH School of Architecture, in the formation of Design Studio 11 – 'Architectures of Interdisciplinarity'. The planning, teaching and evaluation of this studio affiliated to the Architecture Technology subject at the school allowed issues discussed in the thesis to be integrated into a new curriculum, with a focus on the establishment of protocols for interdisciplinary teaching (primarily architects and structural engineers with a strong bias towards design), as well as taking on issues relevant for society at large as a background for design assignments. Direct involvement in teaching was part of the licentiate thesis at an informal level, but the active formulation of briefs and the participation over an extensive period of time (the full academic year) provided a stronger context than before, and is therefore regarded as the third important change of research mode. This is further emphasized by the fact that the majority of the projects included in Projects II are indeed student projects, as opposed to the contents of the Projects I book primarily based on work within the Krets research group [Projects I: p.08].

These three important changes to the conditions of the doctoral thesis are by the author primarily regarded as beneficial to the thesis, in providing alternate approaches to the subject matter. A main argument is here that the thesis itself has always been conducted with a prototypical approach, in the sense of forming methodology (based on precedence as well as new formulations), finding venues to explore (which in each case has been regarded carefully before commencement) and defining an example for future design based research. New approaches emerging during the process have also required that former ones have been redefined, and certain trajectories have become less relevant. At the time of the licentiate, the author was involved with industrial initiatives within the building industry, with the ambition to find overlaps between the iterative design development of digital design prototyping and development platforms for industrial production.[35] The process oriented approach has influenced the arguments of the thesis, but the decision was finally made to put focus on the design aspects at the core of the digital design field. Another trajectory involved independently developed design projects, through which fabrication methods and in extension even production logistics would to be explored. Such work is done extensively as part of research and practice within the digital design field all over the world, and was not considered to provide knowledge unique to the thesis.

Earlier versions of the arguments made in the thesis have been disseminated in different ways during the process. The development of a speculative framework and the exploration of science fiction studies were presented at one conference and as one publication in popular form.[36] A general introduction to the field of digital design was written as a separate publication in Swedish on commission by Arkus, with a strong influence from the findings in the doctoral project.[37] Additional teaching was also done as part of the doctoral candidate position, and while not set up in direct association with the issues explored in the thesis, they have informed certain key areas, such as the view on know edge management and development in practice.[38] Other extracurricular activities of interest include participation in several SmartGeometry events and other conferences[39], as well as board membership of Stockholms Arkitektförening which allowed the author to invite a number of international key actors in the field of digital design in architecture to Sweden for lectures and conversations.[40]

The presented shift of the doctoral project has been crucial to the development of the thesis. This should be regarded as a prototypical mode of progression, which has enabled a shifted scope and the inclusion of valuable new resources. Essential here are the in depth discussions and considerations that took place prior to any of the discussed changes; each decision was thoroughly considered, and emphasis was placed on the contribution to the doctoral project rather than issues external to the thesis. The shift from Architecture to Project Communication, and partly back again, expanded the territory explored followed by new focuses, and provided new insights through the new main advisor and teaching challenges. The chance to direct a focused digital development environment within a major Scandinavian architectural firm has allowed the opportunity to explore digital deployment within a Swedish practice context, and will also provide future research opportunities. The continued investment in teaching studios, and the opportunity to influence and prepare curriculums from scratch was important in order to elevate the teaching studio to an environment interesting to investigate at a research level.

31 Johansson, Rolf, 'Ett explikativt angreppssätt – Fallstudiemetodikens utveckling, logiska grund och betydelse i arkitekturforskningen,' in *Nordic Journal of Architectural Research,* nr 2, 19–28

32 The Division of Project Communication is engaged in education and research on the organization and leadership of the entire construction process from concept and design to production and management, with a focus on communications between the various agents involved in a project.

33 With this shift Professor Örjan Wikforss became main advisor for the doctoral project. Docent Katja Grillner, former main advisor, remained as secondary advisor, which has allowed a consistency in the work and the continuation of a 'research by design' approach.

34 Previous engagements at Scheiwiller Svensson Arkitekter AB included the directorship of 'ssark medialab,' a digital development environment within that firm. Important differences between the two practices, in relation to this thesis, include size and objectives. The former has a strong ambition to be involved with R&D but focuses on a broad perspective with emphasis on sustainability and quality control. The latter certainly has a broad perspective, but the size of the firm, as well as the division into 11 different offices, also allows different focus areas to co-exist.

35 This is in regards to participation in the 'Skanska Xchange' initiative, conducted as an employee at Scheiwiller Svensson Arkitekter AB.

36 Runberger, Jonas, 'Cognitive Estrangement in Digital Design Practice,' paper presented at the *2010 ACSA West Central Fall Conference "Flip Your Field"*, Chicago and Runberger, Jonas, 'The Future Agency of Digital Design in Architecture' in *Conditions #4*, 2010

37 Runberger, Jonas, *Arkitekters Verktyg*, Arkus, 2012

38 Of particular interest is the course in IT Management coordinated by the author at the division of Project Communication at the Department of Industrial Economics and Management in the fall of 2009.

39 Beyond visiting the conference parts of the past two SmartGeometry events (Barcelona 2010 and Copenhagen 2011), the author also facilitated a SmartGeometry pre-workshop in Stockholm in 2009 and acted as advisor and moderator to the *Contemporary practice; Beyond the Crisis* symposium at the KTH in 2010.

40 Stockholms Arkitektförening is the local branch of the Swedish Association of Architects, and the author was a member of the board 2007 - 2012. Several lecturers were invited to do public lectures as well as to participate in reviews and seminars at the KTH School of Architecture.

Reformations

> *"It is in the shaping of the forms of practices (including techniques and logics), rather than the shaping of individual architectural forms, that the concept of the fold becomes important for the development of new architectural form."*

Michael Speaks, Introduction to Earth Moves:
The Furnishing of Territories, 1995[1]

As the digital design field within architecture is maturing and turns to general practice, there may be reason to revisit the nature of the often open-ended explorations that have been facilitated across the field. The past years have seen the establishment of many practices that base their design process on a digital approach, using digital design techniques as natural tools for generating and evaluating design. Often springing from academic experiments in teaching and research, quite personal modes of design have been an important part of the identity of these firms. This may initially have been based on the personal approach of lead designers, followed by new generations fresh out of university and a continuous deployment of new design methodologies in architectural practice.

When digital and computational techniques are adopted and refined for project implementation, new kinds of project processes need to be established. During the early years this has been possible primarily under experimental conditions – controlled environments not subject to all interference and conditions of a project in a professional environment, or as part of new modes of practice that have to re-invent themselves continuously, in which much development is done outside of project budget. Even in the early years of the recent history of digital design in architecture, the ambition was to see new modes of practice as an outcome of new techniques, as indicated in Michael Speaks introduction to Bernard Cache's seminal work above[2]. While this may have been true from the start for many young practitioners who found their individual approach to new digital techniques, and even branded themselves on their mode of operation, architectural practice in general has moved very slowly forward. There has been a discrepancy between experimental users and the general field, and this is emphasized by the way the development of CAD has led to the pursuit of BIM as an overarching system, that searches for generic use rather than specific new potential of its architectural performance.

The purpose of this chapter is to identify contemporary potentials of new modes of digital representation in the form of geometries and their extended function as part of parametric systems – discussed as digital design techniques. In order to do this, it is important to regard the techniques themselves, as important assets for practice, but also the discourse that has emerged around them for the past two decades. Of particular concern is the formation of the digital design field, through practitioners and theorists, often with a focus on process oriented issues. The more recent reformation of the field regards more integrated processes, an expanded discourse and the changed conditions for the architectural discipline and practice when infused with digital design technologies. This reformation will be traced in this chapter through a number of key references, as well as through design project enquiries. The references includes different methodological attempts to establish a comprehensive overview of digital design methods, the formation and reformation of the field through parallel discourses and attempts to define a single unified discourse. Reformations of the digital design discourse can serve several purposes. It is perhaps primarily an attempt to understand additional potentials in the field in order to re-purpose the techniques developed as well as the discourses that have followed.

An important prerequisite for the reasoning of this thesis is that method development within architecture and construction are aimed at improving the capacity to design and construct the built environment, and that economical and technical issues are subordinated to this. This puts a perspective on the introduction of techniques, methods and strategy, but does not entail that economy or technical performance is irrelevant; they are conditions that must be fulfilled but they are not considered to be the main drivers for this development. Another important aspect is that architecture throughout time has been related to technology; as we design artifacts we employ techniques and technology to deepen our understanding of contextual aspects, to form spatial concepts, to develop more complex relations, to construct, communicate and finally produce our surroundings. In addition, the way the public perceives spaces and environments is closely related to contemporary culture, which in turn is deeply associated with technological evolution. We must in turn fully comprehend the conditions for the realization of architecture, and here economical and technical concerns are crucial. Contemporary techniques and methods can improve our ability to understand these issues, but they must be deployed with the understanding that we cannot base our design decisions purely on economical or technical criteria.

From an historical standpoint it is important to remember that the representational techniques that many architects take for granted actually are discoveries, or even inventions, that over time have had a great impact on the architectural expression

through conscious application, while at other times have been more routinely part of daily work. As Alberto Pérez-Goméz suggests, the architect does not do buildings; rather he or she makes "mediating artifacts that make significant buildings possible." The relation between these artifacts and buildings has continuously changed through history. In the late Middle Ages the plan was the footprint of a building, and the elevation represented its "face", and only in the sixteenth century did the section become wildly used, often to describe features that would affect light and shadow. With the introduction of descriptive geometry in the nineteenth century, drawing methods became systemized in order to formally translate between drawing and building, through the efforts to make translations between three-dimensional objects and two-dimensional representations.[3]

Throughout history, representational modes of architecture has enabled or restricted architectural design. As presented by Robin Evans, Hans Scharoun had great difficulty translating the design documentation for the Berlin Philharmonie into construction documents as the project neared completion in the early 1960s, to the extents that the foundations were set in error. Sections had to be produced at short intervals in order to represent the complex interior spaces, but even so, the documentation had no direct relation to the mode of construction.[4] Some 30 years later, Foreign Office Architects faced a similar concern in the design development of the Yokohama Port Terminal. The detailed description of the project was first attempted by drawing sections at shorter intervals, but was finally abandoned in favor of an alternate grid that followed the curvilinear geometry of the project, allowing standardization of the sections to some extent.[5]

In the 1990s Greg Lynn and others promoted the use of animation software in which animation features, morphing procedures or complex modeling techniques were fundamental to the introduction of curves, folds and blobs into architectural discourse of form.[6] Further formal experiments have explored the limits of digital design tools to develop geometries through modeling, or scripting, in pursuit of novel spatial experiences, alternate modes of organizing space and new notions of tectonics[7]. The use of diagrams in architectural design has a long tradition, but has gained further momentum through digital techniques; as organizing movement through smoothly designed spaces[8], structural mapping for complex spatial envelopes[9] or classifying different modes of digital design within a practice[10]. The introduction of fabrication technologies has allowed material experiments that have furthered spatial investigation[11], explored design to production workflows,[12] and introduced new disciplines into the industry[13]. The continued development within the digital field has been suggested to re-invent the architect as a digital craftsman[14], re-introduce the idea of the ornament[15], and enable a performance based practice that can provide sustainable solutions for specific conditions[16]. As the technical development within digital design has progressed, so has the mode of practice. Early work was primarily conducted in an experimental fashion, exploring new spatial potentials based on new design techniques, a parallel to the introduction of CAD-technologies into traditional modes of modeling and drafting. There was an interest to make the process visible, communicated alongside design proposals as drawings and images. As fabrication technologies became more easily accessible, the interest moved to constructing physical prototypes employing a range of technologies such as laser cutting, 3d-printing, cnc-milling and vacuum forming. Experimental practitioners were often also active in teaching, passing on skills to new generations of architects and thereby to a certain extent by-passing the need to test new modes of design through building, accelerating the rate at which new design techniques were disseminated into the architectural community.

With the introduction of digital design tools to the field in general, there is a risk that traditional modes of representation as instruments of design are dismissed. The adaptation to BIM workflows still predominantly provide the basis for floor plans, sections and elevations, often with the purpose to automate drawing production. In this way, they may be regarded as a result of design decisions rather than instruments used to conceive spatial solutions. With the full implementation of BIM solutions, the traditional orthographic representations may be regarded as obsolete, apart from their representational use for communicating design proposals. But how does this affect our way of working, and how can we remain critical to the new conditions that we are facing? Is it obvious that designing in a spatial digital model will provide a better understanding of spatial organization, or can the classical modes of representation still provide valuable information during the design process? Do we no longer need the axonometric altogether, since we have no reason for producing measurable perspective drawings? What is the future role of the orthographic projection that has been the most important representational tool since the 16th century?

1 Speaks, Michael, *Introduction to: Cache, Bernard, Earth Moves: The Furnishing of Territories*, The MIT Press, 1995
2 Ibid. Speaks's reference to the fold alludes to Cache's discussion of Deleuze's use of the term, in relation to how this concept entered architectural discourse.
3 Pérez-Gómez, Alberto & Pelletier, Louise, *Architectural Representation and the Perspecive Hinge*, The MIT Press, 2000
4 Evans, Robin, *The Projective Cast*, The MIT Press, 2000, p.120
5 Ferré, Albert et.al. (eds.), *The Yokohama Project*, Actar, 2002, p.89
6 Lynn's discourse on form in terms such as the continuous, the differentiated, the supple, the curvilinear and the Blob was equally based on enabling techniques in software such as Alias Wavefront and theoretical references to biology, mathematics, philosophy, art and popular culture, as well as in its relation to previous architectural paradigms such as deconstructivist architecture, the idea of the collage or the notion of symmetry. Lynn, Greg, *Folds, Bodies & Blobs: Collected Essays*, La Lettre Volée, 1998
7 See for example: Leach, Neil et. al., *Digital Tectonics*, Wiley Academy, 2004
8 See for example: van Berkel, Ben & Bos, Caroline, *Move 3: Effects, radiant synthetic*, UN Studio & Goose Press, 1999, p.142
9 See for example: Kara, Hanif, 'Diagrams in Structural Engineering: Applied Diagrams – Engineering Precision,' in Garcia, Mark (ed.), *The Diagrams of Architecture, AD Reader*, Wiley, 2010
10 See for example: Kubo, Michael & Ferré, Albert (eds,), *Phylogenesis: foa's ark*, Actar, 2003
11 See for example: Iwamoto, Lisa, *Digital Fabrications: Architectural and Material Techniques*, Princeton Architectural Press, 2009
12 See for example: Kieran, Stephen & Timberlake, James, *Refabricating Architecture*, Mcgraw-Hill Education – Europe, 2003
13 Practices such as Designtoproduction, 3Form and Front Inc. are specialists on developing custom fabrication principles for unique projects, with a primary focus on custom façade systems and to some extents structural systems.
14 See for example: Kolarevic, Branko (ed.), *Architecture in the digital age: design and manufacturing*, Taylor & Francis Ltd, 2005
15 See for example: Moussavi, Farshid & Kubo, Michael (eds.), *The Function of Ornament*, Actar, 2006
16 See for example: Kolarevic, Branco & Malkawi, Ali M. (eds.), *Performative Architecture – Beyond Instrumentality*, Spoon Press, 2005

There are many different views on the role of techniques and tools, as design methods of architecture, and it is not easy to make clear distinctions even within the field of digital design development. One particular aspect that may be worth mentioning is the idea of the virtual. In the intersection between digital tools and classical drawing, the notions of virtual and analogue have come to represent these different modes, at least in mainstream practice. The idea of the virtual did not originate in the emergence of the digital, it entails something that may not be quite real, but still includes many aspects of the real. In this way our so called analogue representations could very well be referred to as virtual, as they are abstractions that represent a certain aspect of reality. This observation is quite important if one considers our new digital techniques not only as tools for representation, but associated with values and even ideologies in an "analogue" way to the classical tools of the trade.

Techniques and Processes in Digital Design

Digital design workflows are typically related to 3D-modeling techniques, the software that supports them, and the technologies that allow design proposals to be visualized, analyzed and materialized. The creation and management of digital 3D-models is essential for CAD and parametric design work, and there are many different modes of operation for such software.[17] The addition of parametric qualities that allow the association of different parts of the model, and the use of external parameters, adds another layer of design potential, but also requires a deeper understanding of how to integrate advanced parametric modeling into a project development workflow. While most CAD packages and 3D-modeling software allow for scripting or programming in order to achieve more advanced ways of creating and managing models, this requires understanding of code, and use has therefore been restricted.

Parametric design or parametric modeling essentially indicates that a 3D-model can include parameters that may be changed in order to update the model. While this may entail basic dimensions such as the thickness of a wall or the width of a window (most object-based CAD-packages are in this sense parametric), the concept has come to relate to the control of more advanced digital models, where extreme differentiation throughout series of complex surfaces are parametrically controlled. Within these cases, issues such as global (overall deformations of a geometry, such as the overall form of a roof) and local control (often the differentiated deformations of smaller elements such as building components or apertures) are often used, and these particular principles are often very simple to develop in the parametric systems available today. Beyond the idea of parametric modeling, a number of concepts are being used in order to further define the principle by which models are created. 'Associative modeling' indicates that the different parts of a model are related to each other; a very basic aspect of parametric design. 'Algorithmic design' often denominates the use of models created through code based instructions, and may entail generative procedures in which the algorithm becomes a co-creator in the design process. 'Emergence' within the context of digital design often indicates complex phenomena that arise from series of relatively simple operations, and is created through algorithmic procedures or agent based systems. 'Computational design' typically indicates a slightly wider field that encompasses parametric and algorithmic design, but may in some cases be directly exchanged for either term. The use of parametric and associative modeling also enables feedback from analytical software to be integrated into the associative model, which allows performance assessment of particular design solutions to inform or even control design decisions. In more advanced versions this feedback can be input in iterative processes, in which a parametric design system can search for local optima within the given design solution space [Contexts I: p.26, p.30 | Projects I: p.40 | Projects II: p.108]. After the turn of the century, parametric software intended specifically for the field of architectural design was being developed, and open source-like environments emerged. With the introduction of parametric applications with graphical interfaces, advanced parametric modeling has been reached a wider audience, something which also has been a characterized the communities that have emerged over the past ten years.[18] The GC User Forum was a locus for early adopters of Bentley's parametric application GenerativeComponents, and provided a platform for shop talk in regards to the use of the application as well as a feedback system for beta testers.[19] The current development of McNeels Grasshopper plug-in, which allows for parametric development within the Rhinoceros NURBS modeler is supported by a similar Grasshopper Forum.[20] Further exchanges on the technical aspects of early parametric development were facilitated at workshops and conferences such as SmartGeometry, ACADIA or eCAADe, as well as journals such as Architectural Design and IJAC, venues that continue to fill an important function as a meeting point for advanced users and specialists.

Formal Procedures and Parametric Techniques

Formalized design methods come natural to the field of digital design; parametric and computational techniques are in essence formalized design steps, or algorithms, that instruct the computer to go through series of geometrical transformations, often associated to evaluation mechanisms, in order to reach a desired result. This has often led to a similar approach in the operation of these techniques; processes are frequently communicated as procedural steps that are closely associated to the digital techniques as such, be it the animation processes of the 1990s, or much later recipes given such as the ones in the Aranda & Lasch Tooling pamphlet [Contexts I: p.58]. For selected parts of a design process, this direct application of procedural steps can be applicable, but for overall project development issues beyond the computational immediately become of greater concern. In order to define a comprehensive overview beyond the techniques themselves, there is a need to establish another kind of methodology, not directly based on the computational techniques themselves, but associated to the conditions of development, and how they can respond to process related conditions beyond the computational. A comprehensive methodology can be approached in different ways, as exemplified by the following attempts – employing a model approach, a task approach, a patterns approach and a competence approach.

Architectural theorist Rivka Oxman has suggested that digital design processes need to be formalized and aligned in order to achieve a deeper interpretation of digital design as a field.[21] Her approach is to categorize into different model types, representing alternate design activities on behalf of the designer. 'Representation' relates to representational media, 'generation' includes the generative process, which in her view operates fundamentally different in digital design and traditional design, 'evaluation' includes analytical and judgmental processes, and 'performance' relates to programmatic and contextual considerations. A further distinction is based on the kinds of interactions facilitated by the model, which in regards to digital design includes a direct interaction with a digital model, interaction with representation generated by a mechanism (such as a non-specialist using a parametric system developed by someone else) and interaction directly with that mechanisms (a specialist developing and modifying the parametric definitions directly). The digital model used in these interactions also identifies ac cording to its capacity, where the 'compound model' is the most advanced, and with in which all other characteristics are combined. She defines this model as a "compound integrated network of enabling design media," and suggests that it creates new digital design thinking that supports "the discrete and differentiated over the generic and typological."[22] Oxman suggests that these classifications indicate that theories and methods of digital design no longer can be conceptualized as the merger of computational tools with conventional formulations of design, and that terms such as digital design thinking and knowing may imply new approaches to design education and pedagogy. For educational situations, she presents a didactic process in which the context of a design development is chosen based on its capacity to demonstrate the behavior and applicability of the selected distinct digital model.[23]

Oxman's proposal for a future compound model suggests that all design interactions take place within a completely associative model, in which direct feedback may inform or even control design decisions. In order to understand the complexity of such a model, it may be interesting to regard the current state of parametric design employing software that in theory could support such thinking. In his PhD on parametric design strategies in Architecture, Roland Hudson bases his definition of parametric design in practice on 'tasks' and 'considerations'.[24] An initial step for a parametric designer is to identify the tasks to engage with, which requires the establishment of the extent of the role of parametric design in contemporary practice, and the stages of the design process in which the parametric designer is participating. Considerations are aspects that need to be taken into account whilst undertaking all tasks. They may involve how the decision process is influenced by the practice, the type of project, the competence of people involved, the stage of design and/or the expected extent of involvement. Hudson indirectly delimits the field of parametric design in practice through his categorization of tasks that the parametric designer faces, including parametric translation, rationalization and evaluation.[25] While an architectural design problem often is ill-structured or wicked [Contexts 1: p.17], Hudson suggests that the construction of a parametric model can be used to assemble a problem space that then can be compared to the structure of the problem. In regards to the procedural character of parametric design, he employs a family of methods defined by B. Chandrasekaran as a reoccurring theme; 'Propose – Critique – Modify'.[26] This entails a proposal of partial or complete design solutions, verification that the proposal is relevant, linked to a critique that indentifies the causes of any failures, followed by a modification of the proposal to satisfy design goals – in effect a prototypical approach to parametric design.

Further enquiries into the formal procedures of digital design methodology requires a certain understanding of the nature of the techniques employed, how they are constituted and how they can be categorized. Robert Woodbury suggests that a com-

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17 Terms such as 'surface modeling', 'solid modeling' and 'object based modeling' are relevant at a basic level and the choice of a particular mode has great significance for the design process. A surface modeling approach may provide high control of articulated surface elements such as building envelopes, but may be restrictive when designing more complex and compound parts. A solid modeling approach is suitable for massing studies as well as the design of compound objects, but may require an in-depth understanding of geometrical principles that become hindering in early stage design phases of complex forms. Object-based approaches are applicable to both surface and solid modeling, and entail the possibility to perform geometrical Boolean operations such as extracting one object from another, but also refer to the association of non-geometrical data to geometrical objects.

18 GenerativeComponents added parametric functionality to Bentley's Microstation CAD package. Grasshopper has done the similar to the Rhinoceros NURBS modeler by McNeel. Maya currently developed by Autodesk was originally intended for animation, but has become frequently used as an architectural design tool due to its potential to handle complex modeling with NURBS polygons and subdivision surfaces, and also supports scripting and parametric control.

19 The GenerativeComponents User Forum was developed pro bono by Jalal ElAli, and was active while GenerativeComponents was in beta stage, before the commercial launch. It is currently off-line, but there is a present forum at Bentley, a part of BE Communities: http://communities.bentley.com/products/products_generativecomponents/f/360.aspx (19/5 2011)

20 http://www.grasshopper3d.com (19/5 2011)

21 Oxman, Rivka, 'Theory and Design in the First Digital Age,' in *Design studies*, Volume 27 Issue 3, Elsevier, 2006, p.235

22 The 'Generation-Evaluation CAD Model' allows the direct integration of certain analytical processes to the design, such as cost estimation, structural behavior or environmental performance, which provides a designer with implicit feedback from the representational model, but explicit feedback from the analysis process. In the' Generative Model,' exemplified with different types of evolutionary models, the designer gives explicit input to the generation and representation components, but receives only implicit (visual) feedback from the digital representation. In the 'Performance-Based Generation Model,' the designer gives explicit input to the performance, generation and representation processes, all explicitly linked to each other, and receives implicit feedback.
Oxman, Rivka, 'Digital Media – New Didactics,' in *Proceedings of the Design Modelling Symposium Berlin 2009*, University of the Arts Berlin, p.35

23 Ibid., p.39

24 Hudson, Roland, *Strategies for parametric design in architecture: An application of practice led research*, PhD Thesis, University of Bath, 2010
Available here: http://opus.bath.ac.uk/20947/1/RHudsonEThesis.pdf (8/8 2011)

25 The task of 'Parametric translation' involves changing non-parametric representations into parametric models. This requires an understanding of the design problem, including what parts of a design is fixed, and what can be changed through parametric development. 'Rationalization' is conducted through the application of known geometrical and construction principles in order to make a project realizable. In a pre-rational approach the geometrical principles are rational from an early design stage, in a post-rational approach constraints to geometry and structure are considered after the conceptual design phase. 'Evaluation' may entail aesthetic assessment through renderings and rapid prototypes, structural performance or energy requirements. Additional tasks proposed by Hudson include local and global 'control' of geometry, the 'generation and testing' of geometries according to different criteria and the 'sharing of information' for collaboration and fabrication.

26 Hudson here refers to: Chandrasekaran, B., 'Design Problem Solving; A Task Analysis,' in *AI magazine*, Volume 11 Issue 4, Winter 1990

plex parametric model is made of (mostly reusable) parts, and introduces the idea of parametric design patterns as a "generic solution to a well-described problem" [27]. Parametric patterns would include problem and solution, as well as other contextual information, and have according Woodbury become a common way to explain design situations. The examples of patterns he refers to have evolved through teaching, primarily in Woodbury's role as an instructor in SmartGeometry events since the organization's inception, and this is also the reason for the choice of GenerativeComponents as the technical platform.[28] This clarifies the ease with which he isolates the design problem; the patterns must be seen as responses to well defined geometrical problems that may be part of an overall much more complex and informal design process. The patterns are regarded to operate on a 'tactical level,' above nodes (a single object with properties such as coordinates, and the smallest unit in GenerativeComponents) but below designs.

In order to establish a framework and template for writing parametric design patterns, Woodbury samples from the field of interaction design, and suggest that a pattern should consist of the following definitions:' Title' (a clear and precise name), 'What' (describing how to put the pattern into action), 'Use When' (providing contextual information needed to know when the pattern is applicable), 'Why' (motivating the pattern and outlining its benefits), 'How' (explaining its mechanics, although the parametric patterns are considered to be self explanatory through their symbolic definition) and 'Samples' (presenting concrete instances of application). The pattern is regarded as formal rhetorical devices that are normative; they suggest their use through their description, and they introduce an alternate way of resolving design problems. They are also meant to "foster communication," in the way that they may allow teams of specialists to immediately understand a complex idea by referring to one or several patterns by name only. Woodbury regards four attributes to be crucial to a pattern. They should be explicit in the way that they should have an exact function; this does not mean that they cannot be altered at any point. They should be partial, and must therefore be composed together in order to provide a parametric design model. They should focus on problem solving, and when well written, they state a problem and provide several clear solutions to it. And finally, they should be abstract, which makes them generic for use in different situations. Design patterns may also be useful for design collaboration as well as knowledge transfer. This often entails editing of patterns for re-use, and here the possibility to easily identify the function of individual parts becomes imperative.[29]

In addition to an understanding of the overall model of potential digital design processes, the tasks faced and the characteristics of its smallest components, it is also relevant to regard the competences involved in collaborative design endeavors. Robert Aish, long time developer of parametric software also suggests relevant associations between learning and collaboration, which in turn requires an understanding of different types of design technique users.[30] According to Aish, the designer that prefers direct modeling expects very quick results, but must realize that this requires intensive manual work. The more changes needed, the more work. From a software developer's perspective, this provokes a question of liberating the designer from a pure mechanical interaction, and allowing software to keep track of all design interactions, allowing backtracking. A designer that prefers associated modeling must expect higher complexity both conceptually and in terms of interaction. The distinction between direct modeling and associative modeling, Aish suggests, is equivalent to using a word processor or a spread sheet; associative modeling gives far more in return, but requires an initial investment of externalizing design logic. The associative modeler is trading manual effort for intellectual effort. This in turn minimizes repetitive remodeling, and allows refinement of the design solution beyond the abilities of the direct modeler. A designer with the same direct modeling skills as his peers, but the additional ability to employ associative modeling has a big advantage.

The third user type, as defined by Aish, is the scripter. This type of modeling demands even more premeditation and work before any results can be shown, but more advanced problems can be handled. Aish suggests that these different types of users have been subject to very different learning curves. The direct modeler has an easy start, and can quickly become advanced, but the outcome is also very restricted. The associative modeler needs to first understand the fundamentals, after that he or she can progress quite fast, but again will soon come to a stop. The scripter needs to learn a lot before achieving anything, but once skill is acquired and a complex script has been developed, the uses can be very versatile. Each of these types has advantages and disadvantages, and Aish suggests that a way forward is to combine the types of modeling in a single software environment. A user would then start as a direct modeler, and can in succession advance up the learning curve while remaining in a familiar design environment. An additional benefit of such software would be to have multiple users working in different modes (direct and associative modeling as well as scripting) on the same model.[31]

The different approaches to formalizations in regards to procedures and techniques presented above are not necessarily in opposition, but reflect different perspectives. While Oxman builds her arguments from a researcher's perspective and a model approach, combining an understanding of the technologies involved and an overview of practices employing digital techniques, Hudson conducts his research from within; as a parametric designer involved in a number of projects. Woodbury arguments are based on his experience from research as well as tutoring students of parametric design, and Aish's view reflects his experience as a software developer close to the user. Oxman describes the activities of digital design through the capacities of different models, and looks for formal principles based on the classification of design activities and models. Her ambition is to set up a viable model that describes the different modes of design within the digital field, in a way that extends classical research into design methods. Hudson's objective is to provide an understanding of the role of the parametric designer as part of a design team through the tasks and consideration that he or she faces, and in extension, he proposes a number of parametric design strategies. Woodbury limits the discussion to the parametric patterns themselves, with little reference to how they may be part of the larger context of a project. The idea of re-use widens the scope, and the

possibility to adapt patterns for alternate situations provides a perspective different from Oxman's compound model approach. Aish considers workflows and the relation between different expertise, and while limited to aspect of a project that can actually be modeled, the direct feedback between different user groups targets an important question. With the integration of digital design methodologies into complex projects, there is a risk of introducing new divides between different parties. A compound model approach depends on highly skilled users in all roles, and suggests that all relevant data is readily available as part of the model.

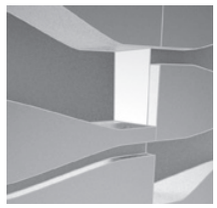
Digital design may be considered and classified from a perspective of models (Oxman), tasks (Hudson), patterns (Woodbury) or competences (Aish), but in addition to these approaches the larger context of the architectural design project can further inform the implementation of digital design methodology, and the discourses that are affiliated with this field. With few exceptions, an overall architectural design process incorporates many steps that are conducted in a range of ways. This may be obvious, but needs to be pointed out since there is a tendency within digital design publication to equal the design process with the computational design process, something that may be even stronger if one adheres to the types of classifications listed above. A more comprehensive, while less formal, understanding may be achieved by examining the employment of digital design methodology within the context of a project. The relation between the overall design process and areas in which computational procedures differs between projects, but in any more advanced design there is a need to understand how this relation is to be facilitated.

In the licentiate thesis, the idea of 'design loops' was introduced as a way to encapsulate parts of the design process in order to be able to study related concepts between different projects, but also suggests that certain aspects of the project could be developed in parallel to the overall process [Projects I: p.07]. This was not meant to break down a project into the well-described problems referred to by Woodbury, nor would they constitute particular classes of design models, well defined tasks or depend on the skill sets of a particular user type. Rather, they can be seen as a narrowing down of the project complexity, conducted in retrospect, but also applicable as a way to define project aspects in which particular design techniques may be employed to explore the design. This is also an initial step towards the formulation of digital design strategies.

The new design projects included in the doctoral thesis have not been fragmented according to the earlier model of the design loop, instead different aspects are regarded in the context of the overall project. This is not an indication that they are less complex than the previous projects; rather it is an attempt to contextualize the digital design techniques as key modes of development. This is particularly clear in the student projects, in which all main aspects are presented in the Projects II section of this thesis. In the Dsearch examples from practice, the presentations are often focused on the aspects developed through modes of digital design, and how these are relevant to the overall project.

In the following design project enquiry, the relation between digital design techniques and project conditions will be discussed, starting with the inclusion of two projects introduced in the licentiate thesis.

Design Project Enquiries



The '**PARCEL**' project was developed through a series of prototypes, and the initial steps were conducted through physical modeling due to the starting point in material folding [Projects I: p.12]. Several of the presented design loops employ digital techniques, including the translation from physical to digital models through direct modeling [Projects I: p.14], the study of recombinatorial potentials [Projects I: p.22], the development of the ornamental network [Projects I: p.28], the preparation for production information [Projects I: p.32] and the later parameterization of the design [Projects I: p.36].

In the PARCEL project, the separated development of a parametric and associative model was aligned with and continued from the initial formal investigation in physical and digital models. The link between the digital model and the production patterns also remained, and each design instance could in principle be produced according to the production principles of the project, the use of steel rule die tools [Projects I: p.35]. This means of production would however only be rational if the parametric model would be used for design refinement of one particular instance. The aggregation of several instances into overall panels [Projects I: pp.42–45], would require a more adaptive production method such as laser cutting. Furthermore, the responsive aspects would have to be reconsidered both in regards to its mate-

27 Woodbury, Robert, *Elements of Parametric Design*, Routledge, 2010

28 All patterns presented in the book are available for download for use in GenerativeComponents. http://www.elementsofparametricdesign.com (11/8 2011)
Limited trials have also been conducted in CATIA and SolidWorks, and a complete list of the equivalent patterns for use with Rhino Grasshopper has been done independently by Tsung-Hsien Wang and Ramesh Krishnamurti. http://www.andrew.cmu.edu/org/tsunghsw-design (11/8 2011)

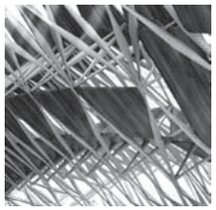
29 In a 2010 experiment on how parametric design can support collaboration, the focus was put on the legibility of the pattern, and here distinctive parts of the overall definition was labeled. The key findings suggested that the size of the pattern was of lesser concern, but the legibility was considerably improved through organization of key nodes, in particular inputs, and clear labels of important nodes. The experiment was facilitated through "thinking-aloud interviews" conducted with architectural students with one year experience in parametric modeling, who would try to understand the functionality of a number of modules they previously had not seen. While Woodbury based his definitions on GenerativeComponents, the facilitators of this experiment employed the Grasshopper plug-in for Rhinoceros, with the significant difference that the graphic representation can be visually and interactively explored to understand its purpose. Davies, Burry & Mark, 'Untangling Parametric Schemata: Enhancing Collaboration through Modular Programming,' in *CAAD Futures 2011 Proceedings*, University of Liége, 2011

30 The idea of the combined learning curve was presented at a seminar facilitated by the author with Aish as special guest in Stockholm in October 2008, and further discussed in an interview with Aish in London in April 2009. A full text of the interview will be published in Swedish in: Runberger, Jonas, *Arkitekters Verktyg*, Arkus, 2012

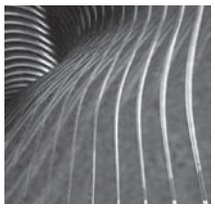
31 Robert Aish has since unveiled the new digital design environment he his coordinating at Autodesk, Design Script, which primarily features scripting interfaces and otherwise mimics the characteristics of GenerativeComponents, as understood from on-line presentations.

rial production as printed circuitry [Projects I: p.32] and in regards to the play between light and form [Projects I: p.52]. In this sense, the 'parametric solution space and fabrication' design loop is a continued development of the design intents derived from earlier steps, that suggests an alternate trajectory for parametric studies and visual evaluations. The tasks and considerations for the parametric model were well defined due to the previous design development. The parametric model provided a 3D geometry for aesthetic evaluation, with a separate 2D model for fabrication.[32] Rather than combining different modeling approaches (and competences), the different approaches were employed in sequence. In this way, the parametric development suggested an alternate trajectory that depended on different production technologies.

The '**SplineGraft**' project integrates parametric studies into the workflow at an early stage as a way of evaluating the performance of its kinetic behavior [Projects I: p.55]. The main concept of a spline deforming in real time was first explored as static states in direct modeling [Projects I: p.69], but simulations of its kinetic transformation were conducted in both parametric models [Projects I: p.67] and in a real time development environment [Projects I: p.73]. The SplineGraft project also features an additional design loop that explored the geometrical principles of its structural rack as a 3D-framework [Projects I: p.80]. While not physically fabricated as part of the project, this rack was expected to provide a more rigid framework for the SplineGraft panels, without affecting its behavior. It would require further refinement to allow for rational production, but similar production means could be employed, and the control circuitry could be integrated after redesign.

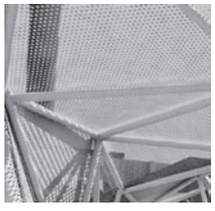


The student project '**Flexible Space Frame**' shares the initiation in material properties with PARCEL and SplineGraft, but explores this as conceptual and performative principles in a more advanced way, through a composite assembly that provides structure and flexibility [Projects II: p.96]. The understanding of the system behavior of the proposed structural assembly was achieved through physical models and diagrammatic drawings, replicated in parametric models through scripting [Projects II: pp.98–99]. These were further developed through direct modeling in order to explore the potential of the structural system as a flexible membrane, spatial organization and spanning structure [Projects II: pp.102–103]. The shifts between physical modeling, direct digital modeling and associative modeling (through scripting) was done at times when one medium was deemed insufficient for exploring a particular aspect. Each separate phase required its own design logic, such as the employment of materials or representations. The overall exploration was set in relation to the context of the project, which in turn set the requirements for the space frame in regards to structure, spatial envelope, span and extents. The full scale of the design proposal could only be explored through a simplified mode of direct modeling, and the detailed articulation through zooming into a section to produce renderings. The project documentation features several modes of representation, primarily originating from either physical or digital models (that were either modeled directly or scripted).



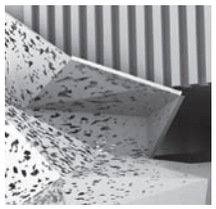
The '**Slumbering Space**' project can be seen as an exercise in setting up a continuous workflow in which several parametric systems directly interface, as well as a prototypical compound model [Projects II: p.108]. The design process entailed revisiting earlier stages, such as the choice to develop the overall envelope as sectioned strips that allowed individual structural evaluation to inform the thickness of the structural ribs. As a design project, it remains internal to its own logic, even though basic programmatic elements such as entrance and vertical communication were considered. In the linear mode of development each subsequent model was regarded as a static construct, despite the fact that all models were developed parametrically. A continued refinement could entail the establishment of a single compound model, including analytical models for structural evaluation and daylight studies. The formal logic employs the individual continuously deforming section in which the aesthetic effect could only be evaluated through perspective renderings.

In the '**Labyrinth Wall Pavilion**,' the initial ambition from the side of the student was to create a generative model, in which all aspects of the conceived spatial principles could be produced [Projects II: p.114]. The build-up of the parametric system could re-use the basic definitions for the distribution of orthogonal plates, to be applied first in the different layers, then on all walls and floor / roof. The initial decision to work with an orthogonal box as basis for the global form, allowed the model to be based on general Cartesian axes – there was no need to check the local situation of elements since all elements in the system shared orientations. A compound approach in which structural analysis would be included in the design model was attempted, but proved to be inadequate due to the complexity of the structural topology – tracing forces through the interconnected web ranging between all layers. Instead, the structural analysis was conducted in an abstracted section model, only to provide basic information on inflection [Projects II: p.119 > img.13].

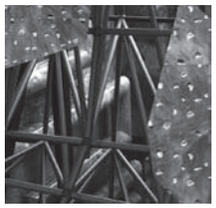


In the '**Share / Mix / Invite**' project the need for self supported walkways set the first conditions for the digital techniques to be employed [Projects II: p.120]. A number of cross sections with shared topology (the number of polygon sides) but different configuration was used to set up a triangulated grid, which early on was analyzed for structural capacity [Projects II: p.120 > img. 08]. Making sure that the system would function in the location where greater distance needed to be bridged, the principle could

then be re-applied in other locations with more intermittent supports. The same principle was used for the roof of the main visitors' center, and adapted to the triangulated main structure of that building, as well as the overall cladding. With only the initial free-standing tube evaluated in terms of structure, similar principles could be applied for the remaining geometries, using a direct modeling approach.

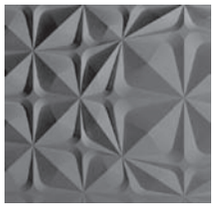


The '**Adjust[ed] Folding**' student project used physical models to define a formal concept, not so much in relation to material performance, but rather in relation to the contextual qualities of the plant [Projects II: pp. 129–130]. The parametric model was developed in order to explore performative aspect in relation to the formal design, either through configuring parts of the triangulated surface structure, or through the control of apertures in individual panels – both in relation to daylight evaluation [Projects II: pp.129–130]. The overall massing and configuration of the design was done in direct and physical modeling (fabricated from the digital model); the geometrical principle allowed for the integration of parametric techniques to explore issues within the overall concept, but does not change the overall design drastically. Again a compound model could have been developed, employing the principles defined in the local investigations on performative aspects.

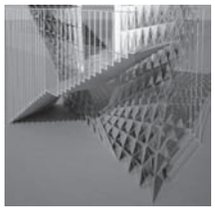


In the '**Amongst the Machines**' project, the student established a basic massing principle early on, based on the main programmatic functions of the given brief (the extension of a combined heat and power plant, with associated public programs) [Projects II: p.132]. This pragmatic approach to the overall composition of the project allowed particular areas to be defined as targets for parametric exploration. A primary subject was the interstitial space between the two main volumes, envisioned as a space frame that also would form and support the secondary program (a climbing center) [Projects II: p.137]. The triangulated logic of the space frame was also employed on the envelope of one of the main volumes through a panelized and articulated skin, and the articulation of the surrounding terrain [Projects II: p.134]. The distributed locations for digital design developments could be explored in a fragmented way. The clear definition of different project aspects as individual masses with individual features developed through digital design techniques in this way provides a basis for the formulation of tasks, and could in a real project have been guiding the formation of teams with different competences.

In the '**Subversive Resilience**' project [Projects II: p.138], initial studies explored spatial organization through parametric means, but these were abandoned in favor of an overall coherent massing model facilitated by direct modeling [Projects II: p.145]. While basic daylight studies evaluated the conditions of the site, and the surfaces suitable for algae farming across the envelope of the design proposal, the emphasis on more advanced parametric models were allocated to the relation between the structural system and the overall form as well as the configuration and distribution of the tubes carrying the microalgae within the structural framework [Projects II: p.140, p.145]. The structure and the framework of algae tubing was however considered to be an important aspect of the articulation of the design pro-posal, making them integral to the design process. The structural framework, in addition, directed the design of base details and apertures between different parts of the building, which made it crucial to refine the structural system prior to the more refined design conducted in direct modeling [Projects II: p.140, p.141]. The overall architectural performance was primarily communicated in classical drawings (plans and sections) and perspectives (Photoshop collages based on renderings), which is a direct result of the compartmentalized development phase.

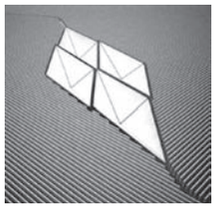


The Dsearch project '**Koggen Ornamental**' had a well defined project aspect (a part of the façade) in a late stage of overall project development, and the process requirements were deemed to allow for the integration of the new design [Projects II: p.146]. The development included a parametric control system for the generation of alternate patterns, with a basic interface for non– specialist engagement in design exploration. The formal articulation of the developed design system was agreed upon with the overall design team through the initial use of references. While the design was never implemented due to change of conditions from the producer, the project shows a potential for very late engagement in a project process if the project aspect is clearly defined.



The Dsearch project '**Reframe**' involved the parametric adaptation of a previous schematic design for a stairwell with an integrated partition that would control and distribute daylight between different floor levels [Projects II: p.152]. The parametric development included means to explore different variants of the partition, introduced alternative circulation routes, and deep component based truss-like partition system that could be reconfigured pending light simulations. It also includes fabrication planning elements, in the automatic generation and nesting of components ready for fabrication through laser cutting or similar technology. The partition system employs components that are linked to each other in a diagonal way, which Is also reflected in the fabrication principles, which required a reconfiguration of data sets within the parametric definition.

32 The first edition of the licentiate thesis was accompanied by 125 unique laser cut flat packed paper models, configured according to the design solution space presented in that thesis [Projects I: p.40].



The projects aspects for the Dsearch project '**Quality Globe Arena**' were again quite clearly defined, but important decisions that had to be made at this time of the project process required visual representations of the design concept [Projects II: p.158]. The development included the parametric control system for the generation of two integrated paneling systems of different formal principles, and again a basic interface for non-specialist engagement in design exploration. Early formal studies had to be conducted for rendering key views of the particular area, to be later developed into a scheme that could be employed for the complete project aspect. In this case, two versions of the development were required; a basic parametric system was developed in short time, and a comprehensive development in preparation for the commencement of the project. At the current stage of development, the Quality Globe Arena study can be seen as a single project aspect developed through a series of parametric design patterns, open to adaptation by a non-specialist designer.

While the Krets projects presented in the licentiate thesis are well defined and small scale projects, the different project aspects present a complexity that can be related to that of a full scale architectural scheme. As such, the approach to employ multiple models, especially in cases in which the development follows an innovative approach in the sense that the design task is quite unknown beforehand, also provides valuable information for more comprehensive project processes. The multiple modes of representational techniques within the SplineGraft project, as a result of the explorative design process included kinetic performance, was tested in physical models (for mechanical and material characteristics), direct modeling (for static formal evaluation), parametric models (that mimicked kinetic behavior in an unsatisfactory way) and scripted Processing models (for actual kinetic simulation). As a project, it depends on all indivi-dual parts, several of which were not necessary to model in a parametric way, there was no need for a complete compound model. The distinctive fields of competences (such as parametric modeling and scripting) were in this way separated, simplifying the development within the design team. The independent parametric study for the PARCEL project would have required more resources in the early design phase, and would have changed the conditions for the continued development [Projects I: p.10]. The requirements for integrating digital design development within a design project may following these arguments, depend on how the process can be adapted, on the sources available, or if and how particular aspects of the design can be developed independent of the overall project development.

The student projects presented in this thesis were the result of a mode of teaching different from the didactic four-step pedagogical process proposed by Rivka Oxman, in that the digital design models employed are contextualized and defined by the overall design project, which follows a fairly traditional design process in which program and site are considered prior to the development of a generic digital type. A specific digital platform has often been selected in order to allow peer learning and as such the design projects can be seen as testing platforms for applicability of certain approaches. In a student project, the relation between the overall design process and particular parametric design development procedures can be handled informally, but even in the educational environment there is a need to be aware of the strategic value of more advanced development, and the requirements needed to accomodate them. The student also often needs to acquire the necessary skills as part of the design development, and in the educational environments presented here, technical training was facilitated as part of the curriculum. The high pace of technical advancement in regards to the parametric tools available, and the unique situation of individual projects, also require continuous learning and method development in professional practice. In order to facilitate this, there is a further need to define the particular characteristics of different modes of digital design practice on a general level. This does not necessarily mean that it is possible to clearly define or classify these characteristics as types of models, specific tasks, generic patterns or specific expertise; to be prescriptive about how a project should be facilitated. An understanding of the different conditions can however prepare participants for challenges ahead, and this can be further supported by documented experiences from prior projects.

The selected student projects present different ways to compartmentalize the development and application of parametric or other advanced digital design methods, but also ways to contextualize them. In some cases the overall process depends on the iterative development of associated parametric systems (Slumbering Space project system [Projects II: p.108]), or the development of such systems in order to move forward with the design process at key points (Flexible Space Frame project [Projects II: p.97]). In these cases it has been important to define strategically important situations in which to initiate such development (or when to move from one model to another), as well as define how the developed system would interact with the overall design process. The objective with the developed systems includes formal generation and evaluation, the simulation of material performance as well as structural evaluation. Other examples present situations in which the development of parametric systems can be done as an encapsulated part of overall design process that could be initiated independent of other requirements (the Adjust[ed] Folding project [Projects II: p.126]), or situations in which part of the design proposal could be isolated with clear interfacing relations to the overall project (Amongst the Machines project [Projects II: p.132]). The objective for development included formal generation and evaluation, as well as evaluation of performance in regards to daylight and structure. In these cases the resources put to use is an issue (primarily time spent), and how the digital design development contributes to the overall design objective. In the case of the Subversive Resilience project, an early idea of using a parametric system for spatial configuration was abandoned partly due to the way it halted the overall design process, and instead, particular aspects of the project were considered, based on the direct modeling of the initial massing principle. If the development for the spatial configuration had been continued (at the risk of not completing the project on time), it may very well have changed the conditions for the project in ways that would have required alternate stra-

tegies for the structural solution and the configuration of the algae tubes.

The references from Dsearch all involve digital design development in which project aspects are fairly well defined, and respond to overall project objectives and considerations. Within this limited context, the development of compound models is more achievable (if considered to represent only the specific project aspect), and could as indicated in the presented cases allow collaborative teams of different competences.

Summary:

- A 'model approach' when classifying digital design methodologies puts emphasis on the capacity of digital models and computational systems, and suggests a systemic approach to further development (Oxman).

- A 'task approach' allows considerations of the field from the perspective of the specialist, can include strategic thinking in regards to optimal processes for the solution of designated problems, but assumes that the formal design approach is formed with the potential of digital design in mind (Hudson).

- A 'pattern approach' regards the smallest re-usable components of parametric systems, and provides a critical undestanding of the benefits of knowledge management in regards to parametric development, but is lacking in considerations on other modes of knowledge production within architectural design practice (Woodbury).

- A 'competence approach' takes overall formation of design teams as well as continuous learning into account, but is focused on tasks already designated as part of a computational design effort (Aish).

- The architectural design project as a context for digital design development adds a complexity to the above definitions, in a way that makes it difficult to provide exact and generic definitions in regards to model approaches, tasks and considerations as well as pure and well defined re-usable patterns. In the context of an overall project, the compound model may require initial development that uses series of different modes of representation, multiple model principles, in which patterns could be developed and re-used and different types of competences are enabled through compartmentalized development areas.

- An early decision on what kind of overall model that is appropriate is often difficult to make, especially in the case of when material properties and physical models are relevant for conceptual development. A fragmentation may be necessary, in which particular project aspects are target for parametric development. While a compound model, as suggested by Oxman, can provide great opportunities in terms of providing analytical feedback to the design model, it may also challenge the possibility to define tasks for parametric development, and the possibility for multi-competence collaboration.

Concepts and Discourses

In the early years of development within the field of digital design practice in architecture the discourse was often focused on process and technique, a natural attitude at a time of exploration. In recent years, several additional discourses have emerged, in which the interest in process and techniques on one hand have been further pursued, but have been paralleled by an interest in the performance and effects achieved by formal innovation, integrated digital workflows and the use of digital fabrication technologies. This part of the doctoral thesis aims at highlighting a number of discourses of particular significance for the arguments presented.

Geometry and Form

The relation between geometry and architecture pre-dates digital and computational techniques, and the two share a common history.[33] There are direct links to the representation of architecture, the construction of architecture, the structural stability of architecture and to other modes of architectural performance. Representational geometry has had a strong role, with modes of representation being crucial to the conception of architecture, the evaluation and communication of its spatial performance and the instructions for how to produce it. Digital design builds on many historical applications of geometry in architecture, in particular those in which geometry moves beyond representation and becomes instrumental, such as providing direct association to the structural behavior of specific geometries or enabling fabrication logics. To go into depth on the role geometry plays for architectural development through history is beyond the scope of this thesis, and while there is historical precedence that directly relate to contemporary explorations of digital and computational potential, such examples are only covered in selection. A primary focus lies on the use of geometrical principles as indirectly as analogy or directly as method in the investigation of current and future digitally enhanced design modes. In relation to the recent advances in digital design, a number of historical discoveries in mathematics are of particular concern.

In Greg Lynn's early theoretical work he looks for an alternative geometrical foundation in his pursuit of formal variance, and he suggests that the abstract space of traditional architecture is set according to Cartesian coordinates, while other fields of design regard the design space as being influenced by forces and motion.[34] Lynn relates this to both features developed within animation software, such as inverse kinematics, and the modeling principles of digital Splines and NURBS, in which control points may be set at fixed Cartesian coordinates, but the resulting curves and surfaces are defined by weighted vectors in space. Lynn does not directly relate to Euclidian geometry[35], but suggests that Spline curves cannot be regarded as points in space; instead they must be seen as flows. He relates these characteristics to gravity, not in the sense of a pure vertical force, but as vectors in space, derived from the integral and differential calculus developed by Leibniz and Newton.[36] In extension, surfaces defined in this way are intrinsically transformable, and Lynn regards them as topological, in reference to topological structures that "can be deformed, with the exception of disruption."[37]

Topology as geometrical principle, refers to the properties that remain unchanged as a geometry is deformed from one form to another, or the way in which geometries topologically can be discerned from each other, such as the difference between a sphere and a torus.[38] An important term for the invariance in topological surfaces is the 'genus' of the surface, which indicates for instance the number of holes in a closed surface, in which a sphere is genus zero and a torus one.

The use of topological surfaces has become a common definition for geometries based on complex surface modeling, and while it refers to the transformable potential of such surfaces all the while the topological characteristics remain, it has become more widespread as a denominator for forms in general, and the specific characteristics of such surfaces in particular. It is thereby distanced from other uses of topology as a concept, such as the organization of structure or infrastructure, common in structural engineering and in urban analytical methods such as Space Syntax.[39] Within the contemporary field there are a number of examples on how topology as in organization of space and infrastructure has become a driving principle that influences form. In the aforementioned Yokohama Port Terminal by Foreign Office Architects, the overall design concept was based on the diagramming of potential movement in the building – the so called "no return diagram" that guided the deformation and connection of a number of layered artificial ground planes.[40] The trefoil knot studied in knot theory was used as an organizational scheme in the Mercedes Benz Museum by UN Studio, in which it becomes a response to the potential movement of the cars contained in the museum.[41] In the Klein Bottle House by McBride Charles Ryan Architects the topological model of the Klein surface informs the spatial organization of a holiday home in respect to internal proximity, views, wind protection and optimal use of topography to minimize excavation.[42]

Minimal surfaces as a geometrical problem was first set up as a mathematical problem by Leonhard Euler and Joseph-Louise Lagrange in 1760, and involved energy-minimizing surfaces (through minimizing surface tension).[43] A regular plane is considered a trivial minimal surface, but over time more complex forms have been identified, the first being the Catenoid; discovered by Euler and Jean Baptiste Meusnier in the middle of the 18th century through the rotation of a catenary curve [Contexts 1: p.16]. While a sphere might be regarded as minimal in the sense of minimal surface-to-volume ratio, it is not seen as a minimal surface in a mathematical sense. The surface types identified so far are categorized into different kinds of periodicity, indicating that they can be repeated with tangential surface conditions, a characteristic also discovered in lipid layers of water, in certain biological assemblies and crystal structures.[44] This approach, as well as others including stretch-fabric models are today possible to digitize through techniques like laser scanning, but computational form-finding techniques such as force density method or dynamic relaxation techniques can replace this.[45] More recent digital experiments with minimal surfaces have been focused on the formal performance of the minimal surface, as a model for spatial differentiation rather than material effi-

ciency. This approach has been explored in a number of design studios within education, in which triply periodic minimal surfaces have been used due to the potential to create continuous surfaces in three directions.[46] Such investigations often employ topological transformations – here indicating that the topology of the minimal surface remains, while the mathematically calculated and energy efficient surface is of lesser concern.

Regular tessellation involve tiling of regular polygons (two dimensions), polyhedra (three dimensions) or n dimension polytypes (n dimensions). There are only three regular tessellations composed of regular polygons distributed symmetrically across a plane; through squares, hexagons and triangles. Johannes Kepler did the first documented studies of tessellations in 1619. In aperiodic tessellation non-repetitive patterns can emerge with a limited number of polygons, most famous being the Penrose tessellation developed by Roger Penrose in the 1970s. Pattern principles that are analogous with Penrose, have also been discovered in Islamic tiling originating from as early as the 15th century.[47] Tiling and tessellation has been used frequently within architecture, but the digital techniques have allowed more advanced application in particular in regards to aperiodic tiling, and the surfaces this is applied to. In the proposal for the Victoria & Albert Museum in London, by Daniel Libeskind, emphasis was put on the tiling strategy for the envelope developed by Arup's Advanced Geometry Group, where an aperiodic tiling principle derived from Robert Amman was modified through a mode of 'selective subdividision'. The variety in density that this produced allowed the designing architects to correlate the façade with the generated tiling pattern in order to achieve more intense fractal patterns in selected areas.[48] The Voronoi tessellation or Voronoi diagram, which has been known since Descartes but was named after Georgy Fedoseevich Voronoi, who refined them in 1908, is a particular method to divide up surfaces or spaces in different cells, related to sets of points distributed across the surface or space. Within digital design, they have been propagating as an easily scripted pattern to the extent that it has been almost exhausted, in particular within experimental practices and in education. It is also not uncommon to mistake the surface and space dividing qualities of Voronoi patterns for having optimal structural characteristics.

Stereotomy was the 17th century term encompassing a number of techniques, including stone cutting, in which the orthographic projections known as traits were employed as drawings that allowed the cutting of complex forms such as arches. In his frequently cited text 'Drawn Stone,' Robin Evens argues that the geometrical art of stone cutting was "permeating the divide between classical architecture and Gothic," suggesting a reevaluation of the evolution of style and the historical relationship between structure and ornament. He suggests that the trait, on which stereotomy depends, can be regarded as a geometrical construct that is situated in between Euclidian geometry (as concerned with magnitudes) and projective geometry[49], in the purpose to employ projection as a method for finding the size and angles of particular stones in a geometrical composite construct.[50] With the development of new digital modeling that allows complex surface modeling, and especially digitally supported fabrication methods, stereotomy has re-emerged as

33 The following brief recollection of the history of geometry is primarily based on Encyclopædia Britannica Online, s. v. 'mathematics,' http://www.britannica.com/EBchecked/topic/369194/mathematics (14/12 2011), MathWorld-A Wolfram Web Resource: http://mathworld.wolfram.com/topics/Geometry.html (21/12 2011) and Mlodinow, Leonard, *Euclid's Window: The Story of Geometry from Parallel Lines to Hyperspace*, Simon & Schuster, 2001

34 Lynn, Greg, *Animate Form*, Princeton Architectural press, 1999 p.22

35 Euclidian geometry, as defined by Euclid in 300 B.C., a few hundred years after mathematics was developed as a theoretical discipline, assembled the Greek knowledge of mathematics and laid the foundation for all that followed. Of particular interest was the understanding of solids and planes, and Euclid mathematically proved the five regular solids described by Plato ca 350 B.C. With the birth of analytical geometry in 17th century France, the relation between algebraic equations and geometric curves was established, and Descartes presented the underlying order of Euclidian geometry, and introduced what we today know as Cartesian coordinates.

36 Gottfried Leibniz and Isaac Newton developed differential and integrative calculus independently of each other, based on their attempts to determine areas and volumes and the calculation of tangents to curves, employing Cartesian algebra.

37 Lynn, Greg, 'Architectural Curvlinearity: The Folded, the Pliant and the Supple,' *Architectural design: Folding in Architecture* vol. 63 (1993):3/4, Wiley, 2004 reprint, p.29

38 Leonhard Euler made the first contributions to topology as field of mathematics with his solution to the Königsberg bridge problem, later to be further developed in the 19th century by Henri Poincaré and Johann Listing.

39 Particular subfields of topology have been applied as organizational principles that also partially define form. An analogy can be made to Reyner Banham's discussion on 'New Brutalism,' where he in a discussion on Smithson's 1953 Sheffield University competition entry suggests that topology – the 'connectivity' of circulation routes, takes precedence before geometry and thereby provides a new mode of composition not based on platonic geometry as a break from classical notions of organizing space. Banham, Reyner, 'The New Brutalism,' *The Architectural review*, 1955 Reprinted in: Banham, Reyner, et.al., *A Critic Writes: Selected Essays*, University of California Press, 1997

40 During the development of the project, this also provided strong links between the circulation and structure, in which programs are located according to shifting qualities of space across the building as well as seasonal changes. Ferré, Albert et.al. (eds.), *The Yokohama Project*, Actar, 2002

41 The trefoil diagram is transformed from its closed configuration, is extended in section to provide vertical movement, and the three loops form three exhibition areas per level and a central vertical void. The overall organization resembles a double helix, and the two main circulatory passageways follow the perimeter of the transformed trefoil, providing two programmatically separated ways of experiencing exhibits, with opportunity to move from one to the other. Picon, Antoine, *Digital Culture in Architecture: An Introduction for the Design professions*, Birkhäuser, 2010 p.82

42 The intuitive combination of a topological spatial diagram and a principle of folding plates allowed construction and the conscious refinement of programmatic relations. Burry, Jane och Burry, Mark, *The New Mathematics of Architecture*, Thames & Hudson, 2010

43 The classical example of immersing a wire frame in soapy water was demonstrated by Joseph Plateau in 1849, whose name was also given to this family of global analysis problems – the Plateau problem. Encyclopædia Britannica Online, s.v. "Plateau problem," http://www.britannica.com/EBchecked/topic/463980/Plateau-problem (14/12 2011)

44 Frei Otto's work with minimal surfaces as well as the Institute for Lightweight Structures at the University of Stuttgart, founded in 1964, indicated that soap-film experiments can work as a method of form-finding for real tensile member systems. This analogue process often depended on photogrammetry for documentation due to the instable characteristics of soap bubbles. See for example: *Information of the Institute for Lightweight Structures (IL) 6*, University Stuttgart, 1973

45 See for example: Bechtold, Martin, *Innovative Surface Structures: Technology and Applications*, Taylor & Francis, 2008

46 See for example: Abrons, Fure & Norell, 'Blush – Reconsidering Minimal Surfaces in Architecture,' student project, UCLA AUD, 2005 – 2006 http://www.b-l-u-s-h.com/ (21/12 2011)

47 Lu, Peter J., Steinhardt, Paul J., 'Decagonal and Quasi-Crystalline Tilings in Medieval Islamic Architecture,' in *Science*, issue 23 February 2007, Vol. 315 no. 5815 pp. 1106–1110

48 Burry, Jane och Burry, Mark, *The New Mathematics of Architecture*, Thames & Hudson, 2010

49 Girard Desargues applied mathematics to the perspective models of the 15th century, and was prominent in the development of projective geometry as a method for constructing perspectives.

50 Evans' main study of traits in stereotomy considers their use in the design and construction of the trompe; a vaulted masonry structure distorted and with its base set in the corner of two walls. In Evan's presentation of the now demolished trompe at the Chateau of Anet, he can only understand the completed geometry by geometrically reconstructing it through the use of the traits documented by its creator Philibert Delorme. Evans, Robin, *The Projective Cast*, The MIT Press, 2000

a new potential for rational fabrication. This is especially pertinent to projects in which natural stone or similar materials are formed into building blocks. Traditional stone cutting techniques can also be combined with computational means to design 'digital traits' such as the work of Mark Burry and others in the continuous construction of Sagrada Familia, in which Antoni Gaudí's partially lost design with forms often based on hyperbolic paraboloids were re-developed through digital modeling. Blocks of granite were produced based on digital templates, both through traditional stone cutting and through CNC disk cutters.[51]

Jane and Mark Burry, both advanced users and developers of parametric techniques for decades, argue that architecture and mathematics have always been closely related through their deep root in geometry – mathematics aimed at the description and definition of space, architecture at the creation of space. [52] They differentiate between projects that have a primary idea based on mathematics, and projects where mathematics is deployed as a problem solver, but also identifies that mathematical ideas have been important for the formation of diverse creative teams of different disciplines. In this way the authors are able to provide an alternate reading of a field of practice through resemblance and differentiation of techniques, and thereby offer a to some degree comprehensive view of a number of tendencies in design practice, even if they disclaim that this in any way is a complete picture of the relationships between mathematics and architecture. Their interest lies in the innovation offered by the integration of mathematical understanding and computation into the design process, but they do not evaluate this innovation as anything more than something new or different. In effect, they provide a common ground between approaches that may be seen as belonging to quite different fields (such as interactive projects, optimized solutions and complex surfaces) through their common relation to mathematics.

Architectural theorist and scholar Mario Carpo, who is well known for his research on Leon Battista Alberti, has recently introduced ideas that link the digital design discourse to the ambitions of the 15th century architect, in his continued strive to devise machines, or at least the idea of machines, that allowed the production of perfect copies.[53] According to Carpo, Alberti avoided representations since he regarded them to be deficient in their role as templates for the production of architecture. He even presented his machines through instructions on how to build them in text and code only, and suggested that the architect should refrain from making any changes to the design once these templates were delivered to the builder, and the building should be a perfect replica of the idea of the architect. In many ways, there is a resemblance in the way we today may devise parametric definitions that in turn form our designs, and there is a parallel in the way BIM is hoped to be the perfect delivery system, in regards to processes and result. Carpo's reading of the digital in architecture is related to modernity in western architecture, and he sees the possibility to make identical copies as an important aspect. If Alberti's contribution to the progress of architecture was part of a first wave, the second was the industrial revolution and mass production.

Carpo furthermore questions the role of the author within the digital paradigm; in particular in regards to contemporary phenomena such as social networks and web 2.0, which in a way contradicts the intentions of Alberti as the architect being the single creator of a design. To Carpo, the nature of parametric models, and implicit to Cache's notion of the objectile, is to allow an end user to manipulate it [Contexts 1: p.18]. It may even indicate a return to pre-Albertian architecture in the sense of an architecture of artisans and craftsmen. He indicates that these issues are often not part of the digital design scene, and that the current intention is to strengthen the role of the architect – an open ended design system might even challenge and threaten some architects. Here, the notion of open source as defined within programming culture, often misinterpreted as free software, may be useful. Programmers have depended on open source models for a long time, a majority of the software being cranked out from the major software developers, including Microsoft, has at least snippets of open source code within them. The early development of digital design methodology gave rise to a renewed interest in geometry beyond the established descriptive and projective geometries dominating the discipline of architecture. Modeling software developed for other industries enabled exploration of spatial types that only rarely had been used before. As the digital field was formed, albeit not in a homogenous way, this also gave reason to re-visit geometry and mathematics. Initial exploration in this direction was primarily looking at form, but as parametric software and readily available scripting environments came in to use, such ventures could examine the mathematics behind such form. The affiliation to geometry through analogy was paralleled by an instrumental approach, in which mathematics became crucial. As presented, these explorations predate the digital era, but have since flourished through education and young practice.

With geometry as an important aspect of architectural design, in particular in relation to the digital field, it is suggested that the early interest in complex form, and geometry that enabled it, was an important part of the formation of the field. This interest remains as part of the identified reformation of the field, during which it has become more profound. The research and design effort put into fabrication is one part of this, in the sense that a deeper understanding of geometry is important for structural efficiency as well as manufacturing logics. This also informs earlier experiments with geometrical constructs that may have been thought of as structural, but in fact has other material performances, such as the voronoi tessellation or the minimal surface problem. In parallel, new historical precedence has been identified, which somewhat defuses the 'newness' of digital design technologies, and enables the discourse to be founded in history. The reformation of the digital design field in regards to geometry is thereby also a rediscovery of already existing relations, and a re-affiliation to architectural history.

Summary:

- ¬ Geometry can have a direct or indirect relation to digital design technologies and techniques, but more often than not there is historical precedence to what may appear as new digital geometry. An understanding of geometry is therefore vital to formal innovation based on digital means.

- ¬ Certain geometrical principles when applied in digital design have become dominant over periods of time, and become types or tropes that are re-used in different contexts.

- ¬ As part of the reformation of the digital design field discussed in this chapter, the role of geometry is being re-assessed, in its role as an instrument to organize space, and configure surfaces. An understanding of the history of geometry in architecture is an important criterion in the continued development of the field.

Performance and Affect

Performance is used in different ways within architectural discourse, and may entail building performance in regards to structure, light or energy related issued as well as architectural performance, ranging from the effect of architectural design on perception and behavior, to how it performs in relation to program or context. In this way, all architecture has multiple performances that change over time depending on shifting climatic conditions, different users and changes in society. It is this ambiguity of the term that is interesting, in that it shows a promise for how technical and architectural performances may work together, but this ambiguity could also establish a divide. This is particularly relevant to the digital design field, in which the term has been used extensively with different connotations. The notion of performance could be applied as an indicator of how well a design proposal is expected to handle technical and climatic issues by linking analytical models to design models, through which iterative procedures can allow optimization towards specific criteria. It could also refer to formal characteristics of a design at a conceptual level, in which the designed form achieves certain qualities that perform at aesthetic as well as structural and other levels. With the introduction of digitally controlled kinetic systems, parts of a building can perform actively at an aesthetic level, often combined with climatic control such as sun shading or ventilation.[54]

With building performance in regards to technical or climatic criteria being the most common use of the term, there is still an ongoing challenge to move from evaluating and proving design ideas to employing performative analysis as part of the design process.[55] While analytical procedures in regards to formal coherence (such as surface continuity), structural capacity (such as optimization for material efficiency) or the flow of gases and fluids (computational fluid dynamics) have been in use for a long time, it is just recently that they are being actively associated to the design tools themselves. The purpose is here to give instant feedback to design decision as constrains, or drive certain design processes.

Material and Technical Performance

Manuel DeLanda relates natural processes to optimization and suggests that while optimization is only subjectively universal, it is fully objective in some areas of reality, where there is a tendency to minimize the difference between kinetic and potential energy. He warns for mistaking 'simplicity' for 'familiarity' and what he regards being one reason for believing that all processes in nature are focused on optimization; making models of reality that are not the simplest possible, but rather the simplest ones to use since they have been made before. With reference to 'phase space' – a space in which all possible states of a system of natural processes are represented, he indicates that in a system with multiple attractors – the forces that deterministically drive a process, the outcome is not pre-determined but becomes a probabilistic question. A system may also have control parameters, such as external temperature, which are incorporated into the model and can serve to connect several phase spaces together in a hierarchical manner, creating a large combinatorial space. DeLanda hereby suggests that while the performance of certain natural systems, such as soap bubbles that minimize surface tension (and thereby surface area) may have a single optimum state (a singularity) in their pure form, will when constrained (for instance by a designer) find a variety of minimal surfaces, something well known to Frei Otto who used similar principles for form finding operations. With no detailed specification, DeLanda suggests that when implemented in computational processes, such evolutionary searches can be efficient and capable for finding forms in several phase spaces at once. To him, such processes are what bring elegance to natural systems.[56]

In digital design, this notion of hierarchies of phase spaces linked together can be related to Oxman's notion of the compound model, but the way that different models, or phase spaces, needs to be linked is crucial to making such an idea reality. Today, this mode of performance as a driver for design is still compartmentalized into different subsystems, often belonging to different disciplines, and adhering to completely different drivers. There are however many attempts to cross such boundaries, and in relation to the digital design field, the link to structural perfor-

51 See for example: Burry, Mark, 'Between Intuition and Process: Parametric design and Rapid Prototyping,' in Kolarevic, Branko (ed.), *Architecture in the digital age: design and manufacturing*, Taylor & Francis Ltd, 2005 and Burry, Mark, *Scripting Cultures: Architectural Design and Programming*, AD Primers, Wiley, 2011

52 The authors suggest a common theme of mathematics and geometry in the digital design field, and classify a number of strategies for the treatment of building envelopes, the organization of a building and the design of responsive environments, differentiated through geometrical approaches, generative and optimizing procedures and performative qualities. Burry, Jane och Burry, Mark, *The New Mathematics of Architecture*, Thames & Hudson, 2010

53 Carpo, Mario, *The Alphabet and the Algorithm*, The MIT Press, 2011 and a lecture at the KTH School of Architecture 2010-01-21.

54 See for example the work of Chuck Hoberman, who combines a deep understanding of geometry with mechanical systems in order to design kinetic structures. http://www.hoberman.com (15/12 2011)

55 See for example: Schwitter, Craig, 'Engineering Complexity: Performance Based Design in Use,' in Kolarevic, Branco and Malkawi, Ali M. (ed.), *Performative Architecture – Beyond Instrumentality,* Spoon Press, 2005

56 DeLanda, Manuel, 'Material Elegance,' *Architectural Design: Elegance*, vol. 77, issue 1, Wiley, 2007, p.18

mance is perhaps the most successful so far. The material form finding procedures employed by architects and engineers such as Antoni Gaudi, Frei Otto and Heinz Isler are being replicated digitally, which allows if not more complex systems to be explored at least more iterations of exploration. Individual experiments that closely relate to material trials include the work by Axel Kilian who has replicated the hanging catenary models employed by Gaudi and others through computational means [Contexts 1: p.16], by which real time feedback is given on changed conditions of the system in the exploration of overall form.[57] There are also numerous completed projects in practice that have employed similar approaches, a well known case being the new Great Court Roof of the British Museum, in which the process of grid relaxation was developed by Chris Williams and Buro Happold.[58] Such custom development also gives way to more generic applications that are aimed at linking the territories of design and structure. Software such as 'Eiform' was developed to generate structural topologies based on initial basic conditions, informed during the automated generation by criteria such as minimum mass and maximum uniformity of the length of structural members.[59] Similarly, 'Topostruct' was developed with the aim of allowing designers and non engineers to familiarize themselves with topology optimization and develop an intuition regarding structural behavior of materials.[60] More recently, plug-ins have been developed for the design software itself, enabling direct structural performance feedback to the design model, such as the Kangaroo plug-in for Rhino and Grasshopper.[61] The way in which digital design will change when such performance feedback is enabled may very well change the overall design process drastically. Design based research has been conducted in this realm for quite some time, and in several locations. There are also trajectories that combine material and computational approaches, something which has been pursued within the Emergent Technologies and Design master program at the Architectural Association (Emtech). Founded in 2001, the program has conducted research into various forms of material systems and their performance as structures, membranes and spatial envelopes, through computational as well as physical means.[62]

Formal Performance

There are also cases in which the notion of performance is less focused on measurable parameters and instead regard the effects produced in different formal approaches. The ideas of effect and affect have been continuously re-surfacing in different ways in the discourse around digital design for some time [Contexts 1: pp.33-36]. At a direct level – the interactions between a user or visitor and material architecture, this involves an architectural performance that involves the induction of particular psychological affects in its beholder. There is little evidence that particular form produces particular affects, rather the discourse identifies particular themes within the notion of affect, and it does so through aesthetic reference rather than psychological insight or scientific investigation. John Rajchman defined the geometries of an affective space as based on an interest in the processes that could enable such a space.[63] Peter Eisenman distinguished between effect and affect; the former has been present in architectural discourse for a long time and regards how architecture performs and serves, and can be exemplifies with the 'form-follows-function' paradigm. Affect, according to Eisenman, is "the conscious aspect of an emotion considered apart from bodily changes" – the sensory response to a physical environment. He also suggests that effectiveness may challenge the potential of architecture to affect; as architecture during history became involved with important functions for society (such as hospitals, libraries, prisons and schools), the symbolic value of architecture diminished.[64] Jeffrey Kipnis later made a remark on Eisenman's discussion on affect, in which he suggested that the architect identified unexpected experiential effects in his own built work, in which sensations rather than an understanding of the formal readings he intended gained increased importance. He wanted to call attention to the fact that the emotional impact of the work arose from the formal structures themselves, rather than from the representations of the architecture, or the intended readings, and termed these new sensations 'affects'.[65]

To a certain extent, an opposition between a process-oriented perspective and a result perspective can be identified – related to using process as an indicator of quality – that is opposed by many actors in the field. The process oriented approach may be seen as shifting from the use of digital tools to enable complex geometries to how it linked with machinic production tools to enable the fabrication and production of such geometries. In parallel, the interest in the effects of digital design technology deployment is manifested in a pursuit of different types of performative qualities. Originating from philosophical thinking and entering the architectural domain as one of several themes borrowed from Gilles Deleuze and Felix Guattari , the notion of affect in relation to sensations has within the digital discourse of architecture become used in a multitude of ways.[66] While this notion is in frequent use informally in lectures and reviews, in particular in the American context, it proves to be quite elusive when one attempts to find more exact descriptions. As affect by definition is subjective, and different individuals may perceive a form differently, an affect can unfold into different affections. In analogue, the concept of affect has been used with different motives and purposes within discourses affiliated to the digital design field. If the primary objective has been to expand the understanding of new architectural forms, and relate it to experiential effects and cultural phenomena, the illusive nature of the term risks deflating the other types of architectural performance. Though it may re-establish the importance of form, it could also become an introverted way of doing this.

Sylvia Lavin has identified certain traits that are valid in order to achieve a contemporary mood of architecture [Contexts 1: p.33]. She regards the contemporary as a speculative terrain, and a key aspect is the distance between cause and effect; the contemporary architectural effect is one that is dissembling and provisionary, with a hidden logic of causality.[67] A particular affect that she puts forward is an affect of tenderness; a way to produce the sensation of both the pain and intimacy of contact between different media, such as art and architecture.[68] Kivi Sotamaa has proposed that 'elegant affect' in architecture is in fact achieved by making the process of its conception invisible, in that traces of the design process will inevitably make an observer focus on understanding process, rather than experiencing the architec-

ture emotionally. Admitting the relevance of process based on digital design tools as embodied in the project, as means of producing complex designs that may rival those of naturally evolved phenomena, he emphasizes that elegance is experienced when these tools are not called to attention.[69] These arguments suggest that affects are stronger if the processes behind architecture remain hidden or obscure, not to interfere with the direct experiences of the observer.

According to Mark Foster Gage, large-scale effects made possible in architecture through digital design allows a shift of aesthetic on a project-by-project basis, but also requires the combination of new design software and expertise and sensibility in the designer. In addition, there is a need for qualifiers; terms such as elegance, which would work as aspirations for the production of new effects. Semiological content would be replaced by visual intelligence employed for the production of "new aesthetically enabled effects," in which design techniques must be coupled with visual and formal expertise. The effect of elegance, Foster Gage has argued, is a "didactic and digestible architectural recipe," and elegance requires differentiation and the emergence of new figural mutations. The ability to curate mutation; producing emergent figures at multiple scales, is for him fundamental for contemporary elegance. The use of surface modeling software provides a framework and a datum against which the expert use of techniques can allow the design of parts in relation to intricate assemblies and the whole, as well as a range of intermediary scale effects.[70] Mattias del Campo and Sandra Manninger have regarded sensibility to be a particular driving force within the discourses of digital design, through "the sensual experiences in the materiality, the luminosity or the chromatics of objects as well as opulent, highly articulated, voluptuous forms." They have proposed that contemporary sensibilities can be described as part quantifiable special effect, and part non-quantifiable affect, or atmospheres. Accordingly, the focus of architectural productions shifts from a discussion driven by functional and performative criteria (in the technical sense) to a discussion driven by the sensual experience within architectural spaces.[71] The Performative Design studio at the KTH School of Architecture defines performance as "the incorporation of contingencies or parameters (material, technical, geometric, programmatic, social and economic) that informs the design process."[72] The studio states an interest in how "technological performance coexists with affective performance," where "technology is subsumed by the production of sensation," to be pursued through study of the relationship between form, performance and affect in contemporary architecture. A number of specific concepts have been defined in the dissemination of the design research conducted in the studio, and an examination of how these concepts are discussed gives further clues on the notion of performance within the studio.[73] In these lines of reasoning, specific kinds of affectnare suggested to be a driving force for design enabled by digital technology as well as an expected outcome of such design. The intention to create affect takes precedence over technical performance and functional use, especially in regards to how projects are evaluated and communicated.

57 Kilian, Axel, 'The Question of the Underlying Model and its Impact on Design,' in Abruzzo, Emily et al. (Ed.), *Models, 306090 Books*, Volume 11, 306090 Inc, New York, 2007, p.208

58 See for example: Williams, Chris, 'Patterns on a Surface: The Reconciliation of the Circle and the Square,' *Nexus Network Journal*, Volume 13, Number 2, 2010, p. 281–295 and Burry, Jane & Burry, Mark, *The New Mathematics of Architecture*, Thames & Hudson, 2010

59 Eiform uses a combination of structural shape grammar and simulated annealing optimization for its generative design process, and was developed by Kristina Shea. Shea, Kristina, 'Directed Randomness,' in Leach, Neil et. al., *Digital Tectonics*, Wiley Academy, 2004

60 In Topostruct boundary conditions and forces gives rise to a variety of structural forms and patterns. The software was developed by Panagiotis Michalatos and Sawako Kaijima in 2008 and is available to download here: http://sawapan.eu/sections/section79_topostruct/download.html (25/11 2011)

61 Kangaroo is a Live Physics engine for simulation, optimization and form-finding directly within Grasshopper developed by Daniel Piker. http://www.grasshopper3d.com/group/kangaroo (25/11 2011)

62 In the Emtech program, a material system is defined as "the complex reciprocity between materiality, form, structure and space, the related processes of production and assembly, and the multitude of performative effects that emanate from the interaction with environmental influences and forces". Hensel, M, Menges, A and Weinstock, M, *Emergent Technologies and Design: Towards a biological paradigm for architecture*, Routledge, 2010, p.48

63 Rajchman, John, *Constructions*, Writing Architecture series, MIT Press, 1997

64 Eisenman, Peter, 'The Affects of Singularity,' in *Architectural Design: Theory & Experimentation: Architectural Ideas for Today and Tomorrow*, Vol 62, No 11/12, p.43

65 In this discussion on the work of Eisenman, Kipnis argues that the increasing importance of affects in the work of the architect was a reason for a new interest in material performance beyond the making of form, and ultimately the requirement of an architecture moves beyond representing new space by way of form becoming fully real in its materiality. Kipnis, Jeffrey, 'P-TR's Progress,' in Todd Gannon (ed), *The Light Construction Reader*, Monacelli Press (New York), 2002, p. 176

66 In their discussion on art, Deleuze and Guattari stipulate that (an object of) art becomes independent from its creator and from its viewer from its creation, being preserved as a block of sensations, or a compound of percepts and affects. Sensations, percepts and affects are according to the authors beings whose validity lies in themselves. Deleuze, Gilles, Guattari, Félix, *What is Philosophy?*, Columbia University Press, 1994

67 Lavin, Sylvia , 'In a contemporary mood,' Hadid, Zaha and Schumacher, Patrik (eds.), *Latent Utopias: Experiments in Contemporary Architecture*, Exhibition Catalogue, Steirischer Herbst, 2002

68 Lavin exemplifies such complex relations with the recent SCI-ARC Gallery exhibition Raw Hide by Jason Payne, in which the cedar shingles on the roof of his Raspberry Field project takes on the qualities of an animal hide, which according to Lavin suggests a tender state of alignment between the animal, human and culture representing a contemporary model of the architectural environment. Lavin, Sylvia, 'Tenderness,' The lecture is available on-line at: http://vimeo.com/29146404 (23/10 2011)

69 Sotamaa, Kivi, "Frozen Void: The Elegant Affect of the Evolved Object", in Rahim, Ali, Jamelle, Hina (eds.), *Architectural Design, Elegance*, vol. 77, issue 1, Wiley, 2007

70 Foster Gage, Mark, 'Deus Ex Machina: From Semiology to the Elegance of Aesthetics,' in *Architectural Design, Elegance,* vol. 77, issue 1, (January/February 2007), Wiley, 2007

71 Del Campo, Mattias, 'Sense and Advanced Sensibility - about the relationship of sensuality, obsessions and advanced design techniques,' in *Proceedings of the Design Modelling Symposium Berlin 2009*, University of the Arts Berlin

72 Course brief Performative Design studio, KTH School of Architecture, part of the Master level curriculum http://www.kth.se/student/kurser/kurs/A42D1C?l=en_UK (27/10 2011)

73 'Protuberance' is defined as a "quality that registers the presence of force coupled with directionality", and that which is protuberant has the capacity to bulge and swell. 'Porosity' is defined as a measure of the void spaces in a material, and the performance of a porous material is determined by the "communication between holes, openings and orientation". 'Venation' is understood as surfaces "that are structurally and visually reinforced with thickened lineaments", providing the "capacity to simultaneously respond to and negotiate issues of structure and subdivision". These three concepts are selected from nine related terms presented in an exhibition of the work of the studio at Färgfabriken 2009. Gow, Karlsson, and Norell, 'Three Concepts of Performative Design: Proturbance, Porosity, Venetion,' in Anstey, Tim et.al (eds.), *KTHA#1*, KTH School of Architecture, 2010, p.48 – 51

One of the most pragmatically defined formal applications of affect can be found in the research documentation from the Function of Ornament studio at Harvard University Graduate School of Design.[74] Farshid Moussavi here argues, based on Deleuze's interpretation, that the perception of an architectural form involves two stages; an initial affect is transmitted by a form, to then be processed by the senses to produce unique "affections – thoughts, emotions and moods," interpreted differently by different people. For the purposes of the research conducted in her studio, she limits her survey to two types of affect, based on optical and acoustical properties. The former is conditioned by the tessellation or complex repetition of a base unit – the smallest structurally independent material entity that defines structural and affective properties in each (architectural) system. The latter is conditioned in different ways by the nature of surrounding surfaces, such as reflective sound. 'Architectural affects' are, according to Moussavi, in this way intrinsically tied to ornaments and building elements that "transmit unique affects" through an interplay between depth and material. She defines particular affects as character traits in building envelopes, in terms like aggregated, banded, latticed, quilted, modular, pleated, moiréd, luminous, camouflaged, multi-directionality, smoothness or crystallinity. The two different approaches that are presented as a basis of affect are materials and forms, in which materials is regarded in a wider conceptual sense, to include light, image, pattern, color or program, and forms can be understood as systems, such as vaults, domes, folded plates, shells or tensile structures.[75] Moussavi and her student have mapped a territory of architectural affects, and the association of form and material brings specificity to the concept, and also sugests that the term is inherent to and transmitted by specific configurations of architectural elements.

When Greg Lynn explored the notion of intricacy in the exhibition with the same name, he employed the work of a number of artists, designers and architects in proposing a new approach to the relation between the architectural detail and the overall structural framework [Contexts I: p.34].[76] Intricacy, according to Lynn, "evokes a particular kind of cohesion, continuity, holism and even organicity." He suggests that here are two types of connected parts that are intricate; aggregations (modular components that are complexly connected to produce a mass) and assemblages (non-modular constructions where each and every part is unique in shape and dimension). The formal composition of the work lies in focus, discussed in terms of "complex connections," "voluptuous undulating surfaces" and "combination of parts that are inextricably smoothed together and fused as a surface." The process of creation of relevance is that of the machine that enables variation and subtlety, rather than design based on the opportunities given by digital design software. While Lynn promotes the formal qualities of intricacy enabled by machinic modes of production, he avoids any argument for form based on computational design techniques when defining intricacy, and does not acknowledge the process as validation or explanation of intricacy. Still, he suggests that intricacy relies on technique rather than figuration, but claims that the work included in the show does not rely on process as validation, but rather shares elegance, rigor, expertise and elegance. Lynn suggests that intricacy "evokes an eroticism for the machine and a desire to make it reproduce organically"; an affect that links machinic processes to the experiential effect of their formal results. Michael Meredith, principle of MOS, argues that the performance of architecture within the digital design field must be related to use, in the double meaning of utility and "theatrical value/relevance," and that architecture should "perform rather than simply form; structurally, environmentally, economically, programmatically, contextually, or in multiple formal arenas." [77] While he considers himself a formalist, Meredith critiques the idea of a performative architecture based on ornament and decoration, and suggest a more complex notion of the performative, avoiding the risk of purely self-referential and introverted experiments in favor of an architecture that combines aspects such as function and context in the design agenda. Lynn and Meredith do not refer to affect per se, but their references to emotional responses or performative behaviors in relation to architectural form relates their views to an aesthetic discourse. They do however suggest additional factors beyond emotional responses, through the relevance of fabrication methods or the importance of multiple architectural performances. This indicates an interest that moves beyond the pure appreciation of form, and breaks the potential division between process, form and a wider performative context.

In her 2007 PhD thesis, Pia Ednie Brown turns towards the performative aspects of architecture during its conception. She identifies affect as a binding force, based on her comparisons of the aesthetic fields of composition and emergence. While her understanding of performative architecture extends to interactive or responsive spatial systems, her analysis of affect is also relevant to other aspects. She introduces the idea of 'mutual affectivity' as an effect of emergent design activities; as the designerengages with the task at hand, he/she is affected in return. Furthermore, she suggests the affective diagram as an "assemblage of relations wherein the power to affect and be affected is distributed." Ednie-Brown uses the term processual architecture for the field of digital design, which indicates her interest in process and behavioral relations of a generative process leading to emerging form, but she also includes the behavior and affects of the designer in this set of relations. The designer becomes an actor, that performs, and each performance strives for a balance between affecting and being affected, and between sensitive responsiveness and determined agency.[78]

Alejandro Zaera-Polo has explored political affect in his investigation of the building envelope as a major signifier for architectural typologies.[79] The envelope includes the crust of the space affected by the construction of its surface, as well as the space that surrounds the object. Zaera-Polo has proposed a holistic view of the envelope, treating it as a single object with no distinction between roof and façade, and a new differentiation into front and back. According to him, the material, organization and structure of the envelope itself gives architecture political agency, in the way that it can assemble and mediate the interests of the multiple stakeholders converging on the contemporary architectural project. It is also regarded as the primary actor for maintaining balance within a building, including technical services for environmental performance, but also through its impact on spatial organization, the delimitation of private and public as well as interior and exterior, and the communication with the

public realm. In relation to current "alternate political practices, such as trends, movements and other affect-driven forms,"[80] the envelope is by Zaera-Polo regarded as a field where identity, security and environmental performance intersect, and it no longer represents the building allegorically (Classicism), nor is it the logical result of a buildings program (Modernism). Referring to the architectural opportunities made available through new digital technology, it is no longer possible to assume that a more regular or differentiated surface pattern, or a more open or closed façade, is better suited at expressing a certain society and ideology. He instead suggests that there is a "resonance" between literal performance – the structural, technical and environmental characteristics of the envelope, and its affect at a political level. Envelopes operate as political devices in the way they regulate the flow of energy and matter in and out of a system – the building – replacing a historical attachment of political performance to the plan in its capacity to organize space and the section that organizes social conditions. In Zaera Polo's argument, the faciality of architecture achieves a new status; abandoning language, signification and syntactical or semantic value (such as patterns of fenestration signifying order, freedom or transparency), and as the relation between a building's skin and its structure becomes more distant, the envelope must take on other roles. They may include technical systems that articulate the exterior as they regulate interior environment, and may even provide symbolic meaning as they become emblematic representations of corporations, cities or nations. The line of reasoning suggests that the multiple performances of building envelopes, as enabled by new technology, can challenge convention, and respond to contemporary social, cultural, economical and political issues. By replacing the notion of typology as dependant on massing principles or internal organization with the dimensional configuration of the envelope, Zaera Polo identifies direct links between new potential modes of formal design and societal issues.

The multiple connotations of the notion of performance, effect and affect is perhaps based in a collective urge to provide a renewed agency to architecture and the field of digital design. The shared terminology may as well pinpoint completely different trajectories. When Rivka Oxman defines performative design as "an integration of evaluative simulation processes with digital 'form generation' and 'form modification models," she also suggests that the term implies that performance itself can become a determinant and method for architectural form.[81] She is clear in that the future of digital design lies in stepping away from 'form making' in favor of 'form finding,' and that this would provide legitimacy for a paradigm shift in architectural practice. The views held in the performative Design studio are more ambitious, in that they aim to include more parameters to the performative model (material, technical, geometric, programmatic, social and economic). In fact all aspects of architectural practice may very well be claimed, but in no way would these parameters be regarded as determinant or over ruling the sensitive act of formal design. An effective performative architecture does not necessarily provide affective sensations, and an articulated and aesthetically complex architecture does not necessarily operate in an effective way in regards to program, technical performance or material efficiency. If there is an opposition between effect and affect, as suggested by Eisenman, this opposition is perhaps best traced in the processes of architectural design. Digital methodologies are however employed both as means to explore both technical and formal performances of architecture, especially in practices that employ linked design and analytical models, and projects that are developed through advanced modeling tools linked to digital fabrication technologies. There are certainly ambitions to unify the two approaches, but the presented references indicate that separate discourses have emerged. Individual projects may have been created through, and motivated by, the combination of strategies, but in order to provide a deeper understanding of the driving forces of future development, it is also interesting to relate to discussions of different modes of practice. Beyond the basic understanding that effect may relate to a more utilitarian functionality of architecture, and affect to an architecture of sensibility and experience, the notion of affect has also been applied to a direct formal performance. This entails discussing the figurative nature of form in terms of the material effects a viewer may associate to form, as in the definitions provided by the Performative Design Studio and the Function of Ornament Studio, or the direct or associated relation between formal appearance and the machinic processes that enabled them such as Lynn's notion of intricacy. These definitions do not regard affect as a subjective experience; instead they aim at developing a contemporary discourse of form, through means such as formal categorization or natural / historical analogies. This in turn suggests formal approaches that challenge the traditional notions of architectural elements, as suggested by Zaera-Polo, which may be seen as producing individual affects and sensations through an architecture that delivers new and unexpected formal expressions. While Zaera-Polo questions whether the "differentiated facialities and tessellations of the envelope" seen in recent projects are "genuine devices to allow the envelope to relate to a larger variety of concerns," respond to "multiple agencies and incorporate specificities" or resort to the" production of spectacular embodiments of global capitalism," his quest to identify political affects is relevant.[82] He critically examines the potential roles of architecture enabled by digital design approaches, but in a wider sense he attempts to bring political

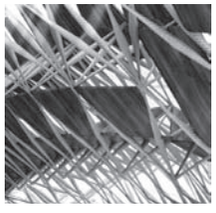
74 Moussavi, Farshid and Kubo, Michael (ed.), *The Function of Ornament*, Actar, 2006
75 Moussavi, Farshid, *The Function of Form*, Actar, 2009
76 Lynn, Greg, 'Intricacy,' text prepared on the occasion of the exhibition *Intricacy*, institute of contemporary art, university of Pennsylvania, 2003
77 Meredit, Michael, 'Never Enough (transform, repeat ad nausea),' in Sakamoto, Tomoko and Ferré, Albert (ed.), *From Control to Design, Parametric / Algorithmic Architecture*, Actar, 2008
78 Ednie-Brown, Pia, *The Aesthetics of Emergence*, Doctoral Thesis, RMIT University, School of Architecture and Design http://issuu.com/pia_edniebrown/docs/02whole (9/10 2011)
79 Zaera-Polo, Alejandro, 'The Politics of the Envelope,' Part I + II, *Log # 13/14 + 16*, Anyone Corporation, 2008/2009
80 Zaera-Polo here refers to the notion of affect as a political force given by Nigel Thrift. To Thrift this entails the passions that motivate and inform democratic political life, exemplified in the mass mediatization of politics, political campaigns treated as marketing, continued contact with voters through blogs etc. and the continuous campaign that surpasses re-election processes. It also relates to the affective dispositions in activism such as alternate forms of bravery. http://underfire.eyebeam.org/?q=node/541 (11/8 2011)
81 Oxman, Rivka, 'Performance-based Design: Current Practices and Research Issues,' in *International Journal for Architectural Computing*, issue 01, volume 06, 2008
82 Zaera-Polo, Alejandro, 'Patterns, Fabrics, Prototypes, Tesselations,' in *Architectural Design: Patterns in Architecture*, vol. 79 issue 6, Wiley, 2009, pp.18 – 27

agency back to architectural practice through re-assessment of recent architectural production.

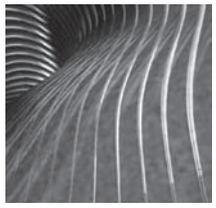
The different discursive approaches in regards to the performative aspects of the digital design field easily trails off into different domains, or different design cultures, that either drives modes of design, or are employing design modes to build discourse. The heterogeneous quality of this discourse perhaps allows a deeper focus in each domain, but there may be a tendency that these trajectories oppose each other. This suggests that an attempt to look for synthesis, or at least partial symbiotic approaches between a culture of aesthetic excellence and high technical performance would be valuable. In addition, such an approach may be useful to bring the agency of digital design beyond an internal discourse to one that is addressing issues in a wider field of architecture, and in extension connecting the important development within the digital design field to society at large. In this pursuit, it is very difficult to provide singular answers or absolute models for the future. Instead, the different modes of performance of architecture considered together may benefit from discussions on examples through relating to individual projects.

The AA Diploma Unit 16 explored how material systems could be further explored in order to become site specific, and perform both at material, structural and architectural levels. This entailed an open ended approach in the sense that projects were formed based on initial material studies, to be deployed at sites that made the material approaches relevant. The Architectures of Interdisciplinarity design studio attempts to combine design process informed by performative evaluation with project situations deemed as being of high significance in the near future and in doing so combines digital design techniques with programmatic and site specific concerns. More complex relations between different modes of architectural performance are more readily discussed as parts of overall projects, as indicated in the references to student work in which these can be traced even if they may not in a technical sense be very advanced. In the design development within Dsearch, and in the experimental prototypes developed within the Krets collaborative presented in the licentiate thesis, there are still a number of performative aspects that are relevant to this argument.

Design Projects Enquiries

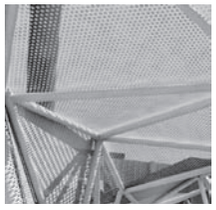


As discussed previously, the '**Flexible Space Frame**' student project explores performance as a design driver in several respects [Projects II: p.96]. The initial material performance of the composite material prototype explored the material characteristics of the two applied materials. For the purposes of the student project, optimization was of lesser concern and the adaptive capacity through geometrical configuration was in focus. The first tests on how this capacity could provide architectural performance, involved basic spatial configurations, in which an active adaptive performance suggested a roofscape with variable apertures, and basic site testing, in which a bridge typology explored access points at different levels, internal connections between those levels, and clearance for passing traffic [Projects II: p.102].
The architectural capacity that provides pedestrian infrastructure was further explored as a ramping structure, and as a spatial network that connects to ground level at multiple points and provides an habitable and programmable elevated landscape [Projects II: pp.102–104]. Digital massing studies at lower resolution explored schematically how larger agglomerates of the system could be developed, and basic programmatic performance was tested in the proposal for the Bexhill-on-Sea Next Wave Shelters & Kiosk Competition [Projects II: pp.106–107]. While functional and programmatic performance was not developed in detail, the series of digital and physical models at different stages explored a spatial performance of continuous variation, in the form of a striated multi-level landscape. The anticipated experiences of the design proposal includes continuous shifts of perspective following gradual level changes, a variation of closed, semi-closed and open environments suitable to the local Tel Aviv climate and sensations of lightness induced through material combinations of delicate filament wound ceramic carbon fiber composite struts and thin timber panels. A gradual change of the configuration of the structure over time would allow for temporary events and alterations to face weather conditions.



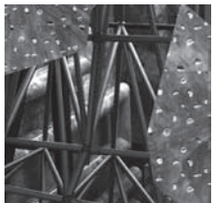
The '**Slumbering Space**' student project was initiated through the generation of a formal envelope with the pure aim of achieving spatial variation, but the subsequent set up of the parametric system introduced a variety of performative criteria [Projects II: p.108]. The structural evaluation of the individual sections defined by the ribbons provides input on the design of the structural part of their assemblies, but also has an impact on how daylight seeps into the internal spaces, and articulates the exterior volume [Projects II: p.112]. While the daylight is also controlled by the distortions of the ribbons, independently of the external elements, their joint performance could have been evaluated by daylight analysis. The programmatic performance of the overall design includes the differentiation of individual elements to accommodate passage from the lower vertical space to the upper horizontal space, as well as the employment of the combined material system to create the entrance. The initial programmatic set-up of a 'slumbering space' and an 'awake space' suggested a darker, calmer space set against a lighter and more active one, but the spatial characteristics were not preconceived. Architecturally, the strongest performance is achieved in the combination of all elements, in the interior space, the gradual formal change between the two spaces supported by changing daylight conditions, and externally, the further articulation provided by the structural members, as well as the relation to the ground.

The '**Labyrinth Wall Pavilion**' student project was initiated in a spatial configuration (an upper and a lower level), with a logical reasoning that the upper level would be lighter and the lower darker. The use of the analogies of the forest canopy and the semi-lit cave further refined the aesthetic ambition at a conceptual level. The initial decision to base the overall design on a cube inserted into the terrain led to a focus on how to generate an articulated, layered envelope, in which much effort was put on parameterizing a random distribution that allowed gradual articulation to achieve the desired spatial effect [Projects II: pp.116–118]. This system also required a structural integrity, and structural performance was analyzed, but did not drive the design. In addition, the connecting elements that make the envelope self supportive are carefully set to be as invisible as possible, in regards to orientation and extension, further setting the visual performance before structural capacity and material efficiency. The completed system fulfilled the spatial effects sought after and retained structural integrity, while providing routes for entering the pavilion, as well as movement between the different levels [Projects II: pp.118–119].

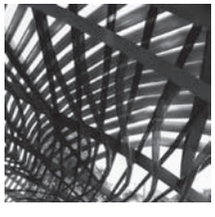


In the '**Mix / Share / Invite**' student project the performative approaches included the articulation of the main visitors' centre and linked programs in order to provide daylight, as well as the structural evaluation of the self-supported passageways [Projects II: p.123]. The triangulation developed as the solution of the geodesic tube structure was formally applied to the main centre in structure as well as glass paneling [Projects II: pp.122–124]. The overall architectural effect when it comes to massing is coherent in regards to geometry and materiality, but may be experienced as an almost arbitrary addition to the conglomerated volumes of the facility. The architectural effort lies instead on the interior experiences for the visitor, whose passage through the main centre and onwards into the tubes is consistent, and provides a reading of the industrial facility that is filtered by the geometrical configuration of structure and panels, as well as the screen printed glass panels in pink [Projects II: pp.124–125].

Climatic and to certain extents structural performance criteria were important in the '**Adjust(ed) Folding**' student project [Projects II: p.126]. The initial climate and daylight analysis were used in order to select the appropriate location of the addition, primarily in regards to the access of daylight and avoidance of shading from the facility itself and the neighboring hill [Projects II: p.129]. The development of the formal concepts of crumbled paper refined as folded surface became the framework for the investigation of several performative principles. It's initial purpose was spatial and architectural, in its potential to create formal unity, and provide interior and exterior spaces with gradients of shelter and connective bridges. Its malleability during early design stages also enabled an articulated relation to the existing structure, ranging from tightly fitted selected surfaces of the facility to free spanning passages between different buildings. The geometrical principle supported iterative daylight performance studies, in which triangulated panels easily could be read based on feedback from the light evaluation model. A second daylight study involved the perforation of particular panels, in which the geometrical configuration allowed treatment of singular panels in identical way (being flat the parallel light rays would have equal effect) and the primary concern would be internal programmatic conditions [Projects II: pp.129–130]. In addition, the triangulated formal principle allowed a basic understanding of the structural performance of the overall system, which could be intuitively confirmed through physical models. Variations of stress on different panels would be handled through differentiation of panel thickness and internal structure, which was only explored in principle. In regards to overall architectural performance, the triangulated systems allows variations between more rational configurations with a horizontal floor and a more fragmented spatial condition, in which sloping floors induce an experience of movement also influencing the sense of direction and visual connections [Projects II: pp.129–131].

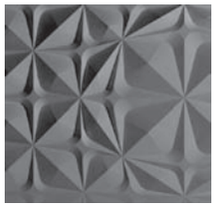


In the '**Amongst the Machine**' student project the architectural approach to the design of a new combined heat and power plant is one of framing; employing architectural means to present the industrial processes within the facility, and creating a framework for the additional public program, in particular the climbing centre. The rational approach to the allocation of the industrial parts of the program and the decision to insert the public program in between the two main volumes also set the conditions for compartmentalized performative studies [Projects II: p.133]. From a structural standpoint, the development of the interstitial space frame as a parametric system combining programmatic needs of the climbing centre for both enclosed volumes and cladding surfaces for climbing purposes. While optimization was not fully conducted in terms of numerical analysis, the principles for structural efficiency were included based on consultation . The re-deployment of the geometrical principles derived from the space frame structure for ground and entrance articulations as well as paneling principles for parts of the main facility, supports a coherent architectural expression that operates both on a larger scale (in terms of massing and envelope), and on a smaller scale (in terms of the use of the artificial ground, different viewpoints to the interior of the facility and the climbing centre) [Projects II: p.133, p.134, p.137].

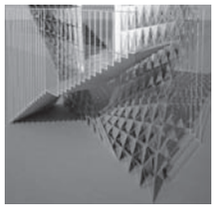


In the '**Subversive Resilience**' student project the initial thesis is that different performative traits can be combined in order to explore unique architectural experiences. This extends to the performance of industrial systems, in the form of the micro algae farming systems, explored through references studies and consultation in order to understand crucial criteria for efficient

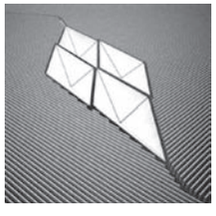
production. This understanding set the conditions for daylight analysis of the site as well as building envelopes, in order to define viable areas for the allocation of the industrial parts of the program [Projects II: p.139]. The overall massing was based on the principle of the hanging catenary, set as the cross section, and ensured envelope surfaces with good daylight conditions. The free-form envelope was developed in relation to ground and solar exposure, with a diagonal diagrid main structure set up as main structure. Structural performance evaluation in terms of deflection was used as feedback to the spacing and angling of the diagrids, which also emphasized the overall shape [Projects I: p.140]. Beyond the technical performance of the algae growth tubes, they were also employed as light filtering devices, set in different layers and employing the different colors of micro algae as an architectural expression. The structural principles also provided a formal challenge in the intersection of the two separate diagrid systems, resolved as variations between open areas with visible structure to walled areas articulated by the structural lines. Internally, the project relies on the combination of spatial variance and the aesthetic expression of the algae farming elements [Projects II: p.143–145].



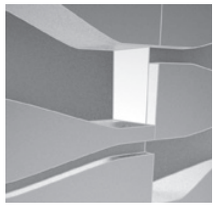
In the '**Koggen Ornament**' Dsearch project the performative aspects lies within the parametric model itself, in particular in regards to the ambition to create a system that enables a non-specialist to explore variants of pattern transitions. With basic modeling skills the control surfaces for the pattern transformation of formal variation and amplitude can be reconfigured, or replaced from a library of stored settings [Projects II: pp.148–151]. The architectural performance is limited to the subtle articulation of the surface of the pre-cast concrete elements, which also receive tactile qualities in their location at ground level.



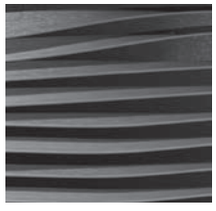
The '**Reframe Dsearch**' project introduced a paneling systems with the potential capacity to reflect and filter light between an upper, well lit level, and a lower level, requiring light control due to the artwork exhibited. While this aspect was not further developed, the capacity to locally control angles and sizes of individual panels can allow this. The system furthermore includes its own structural integrity, achieved through the combination of triangulated panels and steel cable network [Projects II: pp.153–155]. The main architectural performance involves light and sight line filtering, but the presented set-up also includes an integrated stairwell with a landing, creating a space in the midst of the panel.



The parametric system for the '**Quality Globe Hotel**' Dsearch project is also prepared for further exploration by a nonspecialist, in the way overall massing is based on a solid, deformable model and the direction of the lamella systems can be tweaked by adjusting the control lines. The architectural performance involve the creation of a collection of lamella systems that together allow planar lamellas to drape all smooth sides and corners of the overall volume [Projects II: p.160, pp.162–163]. The secondary diamond form paneling system follows the linear directions of any lamella system, and provides local articulation that can be used for light sources and spatial definition in the foyer [Projects II: p.165]. The combined aesthetic performance of the two systems conveys an expression of striation, juxtaposition and local variation.



In the '**PARCEL**' Krets project, the connective performance of the electronic network was tested through simulation, in order to understand how the signal transmission between microphone units and LED and speaker units would behave. Due to the nature of the project, the production required continued testing of the performance of conductivity, and the microprocessor with associated electronic components were built in test beds prior to assembly in the plastic PARCEL units [Projects I: p.49]. The architectural performance combined the reactive behavior facilitated by the electronic network with the formal performance of the assembled PARCEL unit with a differentiated patterning effect, amplified by the site specific color settings [Projects I: p.30]. The recombinatorial capacity of PARCEL adds a user interaction aspect, at least at a conceptual level, through which users may recombine singular units according to certain principles [Projects I: pp.22–23].



The technical performance of the kinetic behavior in the '**Spline Graft**' Krets project was tested at several stages. The first versions of the code controlling the behavior as well as the shape memory alloy actuators were explored in the Shape Modulator prototype, the geometrical principles for the folded panel was explored in parametric models as well as digital simulations, and the technical performance in regards to pulling strength of the actuators was tested in physical rigs [Projects I: p.65, p.67, p.71, p.73]. The architectural performance besides the kinetic behavior included the acoustic dampening effect of the polyurethane foam and the possibility to manipulate the overall geometry through resetting the structural rack [Projects I: p.61].

The different approaches to performance in relation to digital design principles presented through the design project cases serve to identify a diversity of approaches, in which no single factor is driving the project. Material performance has been investigated as conceptual models, in its structural capacity, as kinetic enabler or as conditions for fabrication. Structural elements have been optimized and used as articulation of design proposals, or hidden from view. Architectural performance has been explored through differentiated spaces, articulated surfaces, daylight characteristics, and repeated yet differentiated geometrical principles, as framing for programmatic concerns or as the result of series of performative studies on material, fabrication principles and formal approaches. Most importantly, the projects suggest

the local use of performance evaluation that may not necessarily drive the project, but rather respond to architectural ambitions, or articulate such ambitions. This may entail evaluation of structural principles or capacities, local formal approaches in regards to different daylight needs, network conductivity or kinetic behavior. In some cases active feedback links have provided the opportunity to iteratively evolve formal designs. In others, structural evaluation has been conducted in principle to set the limits of differentiation between structural elements.

Digital Design Tropes

As a parallel to discourses on experiential effect and architectural performance through concepts such as elegance or affect, that still remain internal to specific parts of the field yet distanced to their associated digital design techniques, there may be a need to establish a different kind of categorization. Over the years, certain formal approaches have been proliferating through the digital design communities, often initially as experiments with new software potentials in educational situations. Some of these were initially created through programming or scripting, to later be included into software as off-the-shelf techniques. Others have a pre-history well before the digital era, as based on material or structural performative systems. Within experimental design communities, these approaches often reach a status of saturation, as they are no longer considered innovative, or when their potential is considered fully explored. Some of them have at that stage proven to be successful, as response to certain formal design problems (such as surface division), in a capacity to be efficient (as in structure), or simply because they have become 'memes' that flourish throughout architectural culture. A few of them survive and become frequently deployed for full scale buildings within architectural practice.

This development of formally distinct approaches continues within digital communities, and generates resources that are spread and re-used. Due to the nature of digital design and parametric methodologies, they are open to manipulation within certain boundaries, and as such they cannot be regarded as types. They may rely on combinations of particular geometrical principles, but as architectural constructs their performance goes beyond issues such as surface division or material optimization. They can therefore not be only classified as specific geometries. While some of them prescribe their performance in regards to programmatic or contextual issues, others could be re-deployed in very different situations. They can therefore not be considered to be typologies. To a certain extent, they can be regarded as redeployable prototypes, in particular in cases in which formal principles are intrinsically linked to parametric or computational methods. This also relates them to digital design patterns [Contexts II: p.24], but through the emphasis on their formal performance as primary characteristic, this thesis instead suggests another concept to denominate these approaches; the 'digital design trope'.

There are a number of projects that have employed different types of surface tessellations of space filling principles, and among the specific geometrical principles used, the voronoi has, as discussed previously [Contexts II: p.31], been frequently adopted into the digital design field of architecture most likely due to its inherent capacity to create variation, yet specific recognizable formal traits. With a base in a grid of points, it could also shift from a regular and repetitive state (a regular triangular lattice of points generates a regular honeycomb tessellations of repeated hexagons) to an irregular state, but all cells remain convex polygons.[83] In the earlier years of the formation of the digital design field, the use of voronoi diagrams required basic understanding of programming, but more recently readymade functions have been integrated in parametric design software.[84] Within architecture, the voronoi has been in frequent use for tiling, as well as space division (in which a 3d-version of the voronoi diagram is generated from a 3d-field of points). It is not uncommon to find assumptions that a voronoi diagram performs in an optimized way in regards to structure, which is not automatically the case, especially since triangulated members are not necessarily a part of the geometry.[85] As employed as a tessellation of building envelopes, the principle has been used to look for planar panelization,[86] but it is in examples of more experiential qualities that the use of the voronoi diagram could be regarded as the basis of a digital design trope. In the early work of Tom Wiscombe, voronoi-based geometries were very apparent, in projects such as the 'Stockholm City Library' Competition entry (2006) and the 'Dragonfly' installation (2007), but he has later developed a discourse on 'tracery,' in which seams and joints are articulated to express structure, or to independent painterly effects. Tracery according to Wiscombe does not necessarily express singular performative diagrams (such as structural performance), but rather operates at the level of form and affect.

83 Beyond the use of the formal properties within architectural design, voronoi diagrams are used in a range of scientific areas such as epidemiology, climatology and chemistry. For an overview see: Weisstein, Eric W., 'Voronoi Diagram,' from *MathWorld–A Wolfram Web Resource*. http://mathworld.wolfram.com/VoronoiDiagram.html 1/2 2012 For the mathematical definition see: http://en.wikipedia.org/wiki/Voronoi_diagram (1/2 2012)

84 The Mesh.Triangulation.Voronoi component was introduced in Grasshopper in July 2009, http://www.grasshopper3d.com/forum/topics/grasshopper-060015-prerelease (1/2 2012)

85 This is particularly the case in terms of student work, as experienced by the author in several reviews over the past years. There have however been experiments conducted on structural optimization potentials of 3d-voronoi diagrams, but in this case joints have been regarded as fixed. See: Friedrich, Eva, *The Voronoi Diagram in Structural Optimzation*, Master Thesis, University College London, 2008, p.20 discovery.ucl.ac.uk/14631/1/14631.pdf (12/2 2012)

86 See for example: Troche, Christian, 'TPI – Planar Hexagonal Tessellation of Freeform Surfaces – Manufacturing solutions and design potentials,' in P*roceedings of the Design Modelling Symposium Berlin 2009*, University of the Arts Berlin

It can however create a bridge between technology and ornament that in this way also makes the relation between different performative aspects ambiguous.[87] At a smaller scale, Andrew Kudless of Matsys has explored variations of cellular structures in installation work such as 'C_Wall' (employing voronoi principles, 2006) and 'Manifold' (employing an adapted honeycomb system, 2004), in the pursuit of material influences on geometrical systems.[88] Aranda / Lasch has conducted a number of experiments and installations employing voronoi diagrams further developed into space-packing algorithms, in projects such as 'The Grotto,' 'Peninsulas' and 'Cabinet,' all generated from scripted algorithms, as part of their interest in computation as basis for form.[89] Among large scale built work, the 'Beijing National Swimming Center' by PTW employed a space packing principle in the deep structural façade.[90] Thom faulders and Sean Ahlqvist of Process2 designed a thin, double layered façade screen for the 'Airspace Tokyo' project, using different subdivision and tessellation tools.[91] A recent finalist in the eVolo sky scraper competition even proposed an alternate skyscraper typology based on 3d voronoi diagrams, arguing the cellular nature of the geometry enables future expansion.[92] The different approaches that share the principle of surface or space division may seem disparate and with different objectives, but as a re-occurring theme within the digital design field, it is suggested that they belong to a digital design trope of 'surface/space division'.

Similar arguments could be made about other re-occurring themes. If there was in interest in the continuous surface as an overarching project within digitally based practice in the 1990s, exemplified in the previous discussion on topology by the 'Yokohama Port Terminal' (Foreign Office Architects) and the 'Mercedes Benz Museum' (UN Studio), these pursuits could be seen as shifting in different directions.[93] The surface division trope could be regarded as an ambition to articulate the continuous surface, and add additional performance such as structure or fenestration. If one again considers the minimal surface, its deployment could be regarded as a result of ambitions to further explore the continuous surface, with a better control, and the possibility to articulate the surface through repetition and variance. Pre-digital interest in minimal surface geometries was often based on their material performance, such as Heinz Isler's work on thin shells and form making experiments in concrete.[94] Within the digital design field, the explorations of these geometrical principles could be seen as divided. Within a formal approach, triply periodic minimal surfaces have been employed to as starting point for deformations, in order to achieve controlled yet differentiated spatial models.[95] In pursuits of structural performance, the actual force distribution within surfaces are simulated in form finding processes that may not mimic the identified minimal surface types, but rather operate under similar principles.[96] With these different ambitions in mind, it is still relevant to discuss a 'minimal surface' digital design trope, in which synthesis of the formal and structural/material performances can continue to be pursued.

Beyond these two examples, a number of loosely defined tropes could be identified. The use of lamellas that allow planar elements to provide the experiential effect of complex geometries is in frequent use in different scales. In the '[C] Space pavilion,' custom cut fibre-reinforced concrete panels supported with additional steel frames constitute the overall structure, configured in two intersecting patterns.[97] The 'Banq Restaurant' in Boston by Office dA features an interior cladding system of milled planar panels that provide distinctly different experiential effects depending on viewpoint.[98] In the 'Aqua Tower' in Chicago by Studio Gang, the floor plates emerge from the façade to create an undulating effect, which again changes depending on the viewpoint in the city.[99] In the Projects II section of the thesis, the 'Quality Globe Hotel' project features multiple lamella systems in combination with diamond shaped components [Projects II: p.158], that when further developed could be regarded as a specific type of a 'lamella digital design trope'.

Similar relations could be made with other geometrical principles, such as triangulation for surfacing or space frame definitions [Projects SII: p.136], but in order to be recognized as a trope as introduced in this thesis, it is important to consider different aspects. A geometrical system employed simply to resolve a geometrical problem would not in itself be considered a digital design trope, but if architectural performances in combination with geometrical rationalization for the purpose of geometry, fabrication or assembly could provide reasonable ground for this.

There are many different modes of operation for design trope development. They may be linked to the aesthetic research of a particular practice, preferably in a way that contributes to the continuous development of such a research. As design tropes can be linked to particular design cultures, they could in a specific project be entirely new, but more often they are re-used. If this is the case, they will most likely need to be refined. There is a large number of re-occurring themes within the digital field, and few projects show a completely new trope. They range from applied geometrical principles such as voronoi subdivision of surface or space, triangulation of panels and the continuous surface project to material performance and aesthetic discourses. The tropes that emerged during the formation of the digital design field are often easily recognized, as in the previous examples. In the reformation of the field, existing tropes are being re-deployed in new situations as part of built work, and in many cases it is too soon to say what long term performance they may have. They could certainly be expected to be important in providing architectural identity, in particular as they become a part of society external to the discipline. The potential for high variation sets them apart from earlier architectural tropes, such as the curtain wall or the column slab structure. Their close relation to the computational techniques used to create them also allows them to spread throughout the architectural community as code, rather than only through visual representation. The point here is not that digital design tropes will necessarily completely replace traditional architectural elements in the projects in which they are employed; they could rather be expected to be featured in certain project aspects.

Summary:

- The multiple connotations for the notion of performance in architecture ranges from classical attributes of architecture in relation to program and context, through the technical performance of structure of energy efficiency to aesthetic concepts and discourses.

- The role of performative traits within the digital design field similarly includes both formal attributes emerging within digital design and technical characteristics such as material efficiency or structural optimum.

- Affect is generally referring to the responses in the individual in regards to aesthetic performance, but was formulated and is still frequently used as a concept in an aesthetic discourse that is expanding into political territories.

- The relation between aesthetic concepts and technical concepts in regards to performance and affect are loosely defined, and within a design project this becomes further crucial – technical performance is not necessarily a driver, but rather a constraint that needs to be responded to without canceling intentional architectural performance.

- The idea of the 'digital design trope' is introduced as a classification of certain characteristic design types, that are associated with certain design techniques, and have proliferated throughout the digital design community. It may also be used as a measurement of formal innovation; a new digital design trope developed for a particular project may at a later time re-appear in the projects of others.

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87 To Wiscombe, the geometrical approach to articulate surfaces, and his particular definition of tracing, is a break from the earlier interest of the continuous surface within digital design, enabled with the adoption of new modeling techniques such as subdivisioning as well as cnc-machining and informed by historical references such as the vault ribs and pilasters of the late Baroque.
Wiscombe, Tom, 'The Art of Contemporary Tracery,' in Borden, Gail Peter and Meredith, Michael (eds.), *Matter: Material Processes in Architectural Production*, Routledge, 2012

88 The Dragonfly project by Wiscombe and the C_Wall and Manifold projects by Kudless are both featured under the heading 'folding,' in: Iwamoto, Lisa, *Digital Fabrications: Architectural and Material Techniques*, Princeton Architectural Press, 2009

89 See for example: Aranda, Benjamin & Lasch, Christopher, *Tooling*, Princeton Architectural Press, 2006, p.79 and Hwang, Irene, et.al. (eds.), *Verb natures*, Volume 5, Actar, 2006, p.6

90 In the collaboration with Arup Australia, the Weaire-Phelan geometry for space packing was used, with extensive optimization steps taken to measure structural integrity. Hwang, Irene, et.al. (eds.), *Verb natures*, Volume 5, Actar, 2006, p. 66

91 Ahlqvist, Sean, 'Collaboration and Altered processes,' 2007 Association of Architecture Schools Australasia Conference http://en.scientificcommons.org/24603965 (12/2 2012)

92 Braiman, Geoffrey & Beil, David, *Voronoi Skyscraper*, finalist eVolo skyscraper competition 2011, http://www.evolo.us/architecture/voronoi-skyscraper (12/1 2012)

93 The single surface project also predates the digital design field, see for example Neil Denari's proposal for the Central Glass Ideas Competition 1993.
Denari, Neil M., *Gyroscopic Horizons*, Princeton Architectural press, 1999, p.79

94 See for example: Nordenson, Guy (ed.), *Seven Structural Engineers: The Felix Candela Lectures*, The Museum of Modern Art, New York, 2008, p.16

95 The 'Blush' project uses "variations of self-similar surfaces developed through iterative generation of minimal surface geometry" and "considers figuration as a means of producing affect". Abrons, Fure & Norell, 'Blush - Reconsidering Minimal Surfaces in Architecture,' student project, UCLA AUD, 2005 – 2006 http://www.b-l-u-s-h.com (21/12 2011)

96 See for example: Kilian, Axel, 'The Question of the Underlying Model and its Impact on Design,' in Abruzzo, Emily et al. (Ed.), *Models, 306090 Books*, Volume 11, 306090 Inc, New York, 2007, p.208
The work of Daniel Piker, developer of the Kangaroo plug-in to Grasshopper: http://spacesymmetrystructure.wordpress.com/2009/02/06/rheotomic-surfaces (26/12 2011)

97 This winning proposal for the AADRL10 competition the Architectural Association was designed and developed by Alan Dempsey and Alvin Huang with Adams Kara Taylor and members of the DRL.
Dempsey, Alan & Obuchi, Yusuke, *Nine Problems in the Form of a Pavilion*, Architectural Association Publications, 2010

98 Broome, Beth, 'Banq,' in *Architectural Record*, January, no.1, 2009

99 Gang, Jeanne, 'Fabricating Material Effects: From Robots to Craft-Workers,' in Kolarevic, Branco & Klinger, Kevin (ed.), *Manufacturing Material Effects, Rethinking Design and Making in Architecture*, Routledge, 2008

Practice and Discipline

An important aspect of the reformation this thesis associates with the digital design field is the continued implementation into general architectural practice. In relation to concepts discussed earlier in this chapter, there is also the notion of performative practice, introduced by Stan Allen, and part of the discourse around criticality presented in the licentiate thesis. According to Allen, this is a practice that continuously reworks the limits of the discipline from within, of which the consequences and effects are most valuable. He states that this practice is no static construct, but is rather defined by its movements and trajectories. He even suggests that "there is no theory, there is no practice. There are only practices, which consist of action and agency" and that any act that brings up new ideas or sets up scenarios which impact cultural environments is actually a component of the practice itself.[100] In relation to the digital design field, this may regard initiatives that affect the way projects are handled, but such endeavors may also influence how architectural practice may influence the industry, and in extension provide frameworks for disciplinary development. As experimental digital design practice leaves the premises of free exploration provided in academic contexts and is deployed in professional practice, innovative modes are faced with new conditions. This leads to advancement within the digital design field, as previously experimental techniques need to be aligned with project workflows, but also suggests another level of discourse. The frequency by which digital design advocates operate within both academia and practice also brings new common ground between the two.

Peter Zellner suggests that there is a tendency to shift the discussion from process to result, in terms of performance– This shift is as an effect of a need to "de-tool" digital design as it transcends from an academic activity into practice, and allow for it to continue evolving when faced with new challenges.[101] According to Zellner, this is also reflected in digital design studio teaching, where he identifies trajectories that seek to avoid the direct manifestation of digital tools in the material forms produced (such as patterns resulting from CNC milling paths), representational proofs (such as 3D-geometries unfolded into panels to prove fabrication) or automated design steps (scripts that generate form). He suggests that a new architectural robustness is needed, in which traditional disciplinary issues are again incorporated in order to move beyond digital architecture as a proto-form or mere image. As an extension to the requirements for physical manifestation of digital work, he also suggests that social and political purposes for the continued development of digital design may follow.

There are different approaches on how digital design development adopts to issues of practice. Within many architecture and engineering firms specialist teams have been formed in order to develop digital methodology, and to integrate it into project workflows. Foster and Partners initiated their Specialist Modeling Group (SMG) in 1997, an in-house consultancy aimed at helping design teams to explore solutions rapidly and communicate data to clients, consultants and contractors. One of the primary goals has been to develop control mechanisms that drive geometry in response to relationships such as performance parameters and design criteria. The team has made contributions to more than a hundred projects, in which they often work with the rationalization of complex geometries for fabrication and performance purposes. A main function is to develop bespoke analysis tools, but there is also an emphasis on pedagogy, workflow consultancy and issues of knowledge transfer between project members.[102] The Computation and Design Group (CO|DE) at Zaha Hadid Architects is an informal assembly with expertise in advanced modeling, parametric design tools and programming that support design development in order to "explore multiple related design iterations across a solution field of desirable shapes, while maintaining a common codified geometric logic."[103] The Aedas Research&Development teams focus on three main areas of research for project implementation; computational design, advanced modeling and sustainable design. The teams have an evidence focused agenda and create tools and methods that are tested against live constraints and deliverables in projects.[104] Skidmore Owings & Merrill also include three teams; the Digital Design Group (DDG) that implements new CAD technologies and BIM, the Advanced Design Group that has a focus on sustainable design, and Blackbox, founded in 2007 with the purpose of developing and leveraging parametric and algorithmic processes to generate new approaches to architectural, interior and urban design. The studio is defined as an applied research source focused primarily on the search for the optimal and the novel.[105] These initiatives within architectural firms are also paralleled by similar formations within engineering firms, primarily within structural engineering. The Advance Geometry Unit of Arup Engineers (Arup AGU) was formed in 2000 and has since been part of a large number of projects in which digital design tools have supported the construction of complex formal proposals, both as engineering consultants and as initiators of projects. A primary concern has been to investigate new aesthetics, based on prescriptions of form developed within the unit.[106] P.art, also set up in 2000, designates itself as one of the organizational strands within Adams Kara Taylor Structural and Civil Engineers, and aims at bringing together designers from a variety of backgrounds in order to find and develop a toolkit of design approaches and methodologies for project deployment.[107] Buro Happold operates the Software Analysis and Research technology (SMART Solutions), focusing on finite element analysis,nonlinear structural analysis, form finding and optimization as well as simulation and design rationalization, and previously also the Generative Geometry Group functioning as an interface between architects and engineers.[108]

The formation of specialist teams has been fundamental for many of the large scale architectural projects developed for the past ten years, and their investigations have also resulted in collaborations with other disciplines, such as art. There are also other initiatives that move beyond the issues of form making and the construction of individual projects. A architecturally as well as commercially successful example of such a practice can be found in SHoP Architects, who argue for a performative practice in the sense of basing design on contextual parameters; site, program, budget, and exploring hidden potentials in them through the means of digital design tools.[109] Beyond the employment of specialists that can provide digital expertise in a wide

range of projects, SHoP also looks at alternate business models, including their own construction division, operating as an integrator between the architectural practice and the industry.[110]

There are also new specialist firms being established in which digital design principles and computation have been fundamental, particularly in regards to design refinement for fabrication and production. Gehry Technologies, an offspring of the research and development teams at Gehry Partners, was established in 2002 as a developer of technology and a consultancy for advanced BIM services. They developed the Digital project application based on Dassault Systemes CATIA CAD package.[111] Design-toproduction was established in 2006 as an offspring of research in digital fabrication facilitated at the CAAD chair at the ETH Zürich. They employ an interdisciplinary team to support architects and engineers in order to bridge the gap between a design proposal and its realization. An important aspect of their work is the realization that fabrication methods do not scale, and that complex projects often require customized production methods. They therefore operate as advisors to designers for the early stages as well as consultants during design rationalization when digital workflows are developed to support the link between consultant teams and manufacturers.[112] Newtecnic take the role of façade designers for architecturally and technically challenging projects, and develop project specific façade systems. With a small team of specialist architects, they have been collaborating with a range of architects, and have also contributed to the sharing of knowledge through the publication of reference material for students.[113]

Beyond the formation of specialist teams within existing practices, and the establishment of specialist firms for different new compartmentalized parts of the design and construction processes, there are also newly established architectural practices founded on digital expertise that regard digital methodology as an integral part of their daily business. More often than not, these firms combine practice with research, frequently conducted within educational design studios. Kieran Timberlake Associates, founded in 1984, emphasize process before specific expression in regards to digital techniques.[114] Reiser + Umemoto, founded in 1986, have developed a large number of conceptual designs and been actively engaged in the discourse, and with recent competition wins they are moving into large scale projects.[115] UN Studio, founded in 1988, are working globally with several completed large scale projects.[116] Asymptote, founded in 1989, was primarily involved in small scale conceptual projects but has recently completed The YAS hotel near Abu Dhabi.[117] Preston Scott Cohen Inc., also founded in 1989, known for conceptual designs based on perspective deformations, has recently completed several large scale projects.[118] Recently disbanded Office dA, founded in 1990, completed a large number of small to medium scaled projects.[119] Also recently disbanded, Foreign Office Architects was founded in 1993 and after their much celebrated Yokohama Port Terminal completed a number of small and medium sized projects, postclassified according to their contributions to the practice as a whole.[120] The Berlin based practice of Barkow Leibinger (established in 1993) supports their practice with research conducted primarily through digital and physical prototyping. A primary interest is the use of alternative, digitally driven manufacturing and assembling technologies, and how those can be incorporated in construction projects. This is conducted in a way that reverses the "normative design process," by starting with a material, which leads to a detail, then prototype followed by program and site. Founders Frank Barkow and Regine Leibinger have been teaching in the US and in Europe at a number of universities.[121] Chicago based Studio Gang (established in 1997) are interested in combining digital fabrication technology with on-site construction methods, and the firm is profiled as being research oriented, particularly in regards to material fabrication combining digital design expertise with manual craftsmanship. The recently com-

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100 Stan Allen, *Practice: architecture, technique and representation*, G+B Arts International, 2000. See also: [Contexts I: p.41]

101 Zellners's arguments are based on new trajectories taught at UCLA and SCI-Arc, discussed with a number of faculty members. Zellner, Peter, 'De-Tooling,' in *A+U: The New Ecologies in Los Angeles – Design and Technology*, 2008

102 See for example: Whitehead, Hugh, et.al., 'Driving an Ecological Agenda with Project-led Research,' in *Architectural Design: Experimental Green Strategies: Redefining Ecological Design Research*, vol. 81 issue 6, Wiley, 2011

103 The activites of ZHA CODE are not well published, but mentioned by Christiano Ceccato in: Ceccato, Christiano, 'The Master-Builder-Geometer,' in Ceccato, Hesselgren, Pauly, Pottman, Wallner (ed.), *Advances in Architectural Geometry 2010*, Springer, 2010

104 See for example: Derix, Christian, et.al., 'Feedback Architecture,' in *Architectural Design: Experimental Green Strategies: Redefining Ecological Design Research*, vol. 81 Issue 6, (November/December 2011), Wiley, 2011

105 See for example: http://www.som.com/content.cfm/services_blackbox 4/12 2011

106 See for example: Sakamoto, Tomoko and Ferré, Albert (ed.), *From Control to Design, Parametric / Algorithmic Architecture*, Actar, 2008

107 Ibid. and Anstey, Tim, 'Discourse Networks and the Digital' and Speaks, Michael, 'Design Thinking with Adams Kara Taylor,' both in Kara, Hanif (ed.), *Design Engineering AKT*, Actar, 2009

108 For Buro Happold Smart Solutions see: http://www.burohappold.com/buildings/building-fabric/smart-solutions 4/12 2011 and for the work of the Generative Geometry Group see: El Ali, Jalal, 'The Efficiently Formed Building,' in Littlefield, David (ed), *Space Craft: Developments in Architectural Computing*, RIBA Publishing, 2008

109 Kedan, Elite, et al., (eds.), *Provisional – Emerging Modes of Architectural Practice USA*, Princeton Architectural Press, 2010

110 SHoP Construction was initiated in 2007 with the ambition to utilize new digital technology to provide sustainable construction management. http://www.shop-construction.com (3/12 2011)

111 See: Shelden, Dennis, 'Information Modelling as a Paradigm Shift,' in *Architectural Design, Closing the Gap: Information Models in Contemporary Design Practice*, vol. 79 Issue 2, (March/April 2009), Wiley, 2009 and http://www.gehrytechnologies.com (6/12 2011)

112 Discussion with co-founder Fabian Scheurer 10/3 2011. See also: Scheurer, Fabian, 'Design to Production: Building Complex Design,' in Borgart, Andrew, et.al. (org.), A*bstracts, Programme and Practical Informaiton of the First International Colloquium of Free Form Design*, 2006, and Scheurer, Fabian, 'Size Matters: Digital Manufacturing in Architecture,' in Abruzzo, Emily and Solomon, Jonathan D. (ed.), *306090 Books*, *Dimension*, Volume 12, September 2008

113 See for example: Watts, Andrew, *Modern Construction Handbook*, Springer, 2009

114 Kieran, Stephen and Timberlake, James, *Refabricating Architecture*, Mcgraw-Hill Education – Europe, 2003

115 Reiser, Jesse, *Atlas of Novel Tectonics / Reiser+Umemoto*, Princeton Architectural Press, 2006

116 Van Berkel, Ben & Bos, Caroline, *UN Studio: Design Models - Architecture, Urbanism, Infrastructure*, Rizzoli, 2006

117 http://www.asymptote.net (11/1 2012)

118 http://www.pscohen.com (11/1 2012)

119 http://www.officeda.com (7/10 2012)

120 Kubo, Michael & Ferré, Albert (eds,), *Phylogenesis: foa's ark*, Actar, 2003

121 Barkow Leibinger, *An Atlas of Fabrication*, Architectural Association, 2009

pleted 'Aqua Tower' is a residential story high-rise in Chicago, featuring custom cast floor plates for each floor. Founder Jeanne Gang is also teaching at the Illinois Institute of Technology.[122]

A common denominator between these practices apart from the explicit use of digital design principles is the involvement in teaching, often employed as a mode of research. They are pursuing new modes of practice by exploring new technologies within teaching, and deploying their discoveries within practice, and together they give a differentiated view on what issues are relevant for the conditions they face as individual firms. While numerous events and publications have themed the discoveries over the years, very few of the listed practices outline one single trajectory for the future development of the architectural discipline. As a collective of design researchers exploring how digital experimentation can be made relevant to practice, they outline a diverse field, which continuously reforms itself through the parallel efforts of many small parts. The notion of digital design tropes is again relevant here, in the sense that such tropes are part of the dissemination from and between such practices. Specific tropes may very well emerge between digital design specialists belonging to different architectural practices, and later be deployed within these respective practices in different ways. In the collective efforts, as well as individual endeavors, these practices are an important part of the ongoing reformation of the digital design field, in a way that also is very significant for general architectural practice.

Besides common trajectories and strands of digital design research emerging within this heterogeneous field of digital design practice, there are also attempts to unify the field through the definition of common overarching goals and approaches. One of the most ambitious, and perhaps also most refuted, proposals has been delivered by Patrik Schumacher. He first introduced his Parametricist Manifesto at the 11th Venice Architecture Biennale in 2008. In this statement Schumacher suggests that Parametricism can be defined as a mature style in that a "parametric paradigm is becoming pervasive" in the avant garde of contemporary architecture, primarily based on the discourse of the digital design field. The manifesto defines the key issues to be addressed by this avant garde to develop an "architectural and urban repertoire" that can organize and articulate the increased complexity of society – a post-fordist society. This activity concerns all design activity from urbanism to tectonic detail, interior furnishing and product design – a "total fluidity on all scales."[123]

In the further definition of Parametricism, Schumacher defines five agendas in which this style made possible through digital design thinking can operate. 'Parametric accentuation' operates at the scale of building components, with the objective to "enhance the overall sense of organic integration" between overall form and detail. 'Parametric Figuration' regards "complex configurations with multiple readings," which can be understood as massing and envelope principles. 'Parametric Urbanism' or 'Deep Relationality' entails a "systematic modulation of morphologies" that can produce "powerful urban effects and facilitate field orientation," and can be seen as the parametric control over an array of building forms that produces differentiation between similar forms (such as gradually shifting scale). The 'Parametric Inter-articulation of Sub-systems' agenda suggests that multiple sub-systems are associated, such as envelope, structure and internal subdivision, allowing them to be controlled together and depend on each other. The final agenda, 'Parametric Responsiveness,' regards the real-time response of built structure to occupation patterns and other conditions, and includes kinetic components that actively could change the environments over time.[124]

Schumacher argues that beyond any aesthetic coherence within the digital design field, it is the "wide-spread, long-term consistency of shared design ambitions/problems" that justifies the claim for the definition of a style, and he refers to the frequent use of concepts such as 'differentiation', 'versioning', 'iteration' and 'mass customization' within the field to capture this consistency. He further defines these shared ambitions through a number of dogmas (positive heuristics) and taboos (negative heuristics); guiding design with respect to both formal and functional aspects. Accordingly, parametricism strives for forms that are parametrically malleable, lawfully differentiated systems that are correlated to each other, and functions that are understood as variable fields of activities rather than reductions to generic typologies.

An important aspect of Schumacher's arguments for a new style lies in his definition of styles in relation to the avant garde. He regards styles as design research programs and sees the evolution of architectural media (the design techniques that are employed) as a parallel to the evolution of architecture, and both geared towards innovation. Architectural research, that is research that is involved with the design process itself through experimental design and prototyping, is inherent to avant garde in his opinion. In practice, commissions that allow this provide "a playing field for formal research and spatial intervention where both functional and economic performance criteria are less stringent then in the 'commercial sector' of mainstream architecture."[125] Over time, according to Schumacher, the discipline develops through a progression of distinct styles, regulated by different levels of determination, where 'Codes' are very stable and establish long term unity of the system, 'Styles' provide medium– term programs that frames series or clusters of work and 'Themes' are project focused and coheres all design decisions within a project. A primary field for development is again identified in the avant garde, where new form-function relations are seen as crucial for design innovation. The duality of a search for functions for new form, and form for new function is defined as double contingency, and he suggests that old formulas such as 'form follows function' or 'function follows form' are too simplified, and he instead suggest an oscillating 'form follows function follows form'. The capacity of a style to organize and articulate increasing societal complexity is argued as dependant on the capacity to analyze, vary and recombine the 'elements' of the particular style. His hypothesis here is that the progression of styles follows a "trajectory of repertoire expansion that allows the discipline to increase its capacity to handle complexity."[126] The design research program is based on an initial speculative hypothesis internal to the discipline, and that is tested in iterations through projects. The first trials will most often

fail, and the supporting program is for this reason often set up in an academic context, but further societal issues are incorporated, and improvements should ensure that the line of development results in architecture with a "superior level of performance."[127] This also entails that in the avant garde project, it is not the specific building proposal that is tested; it is the style itself.

This "quest for comprehensiveness" of the digital design field led Schumacher to try to define a unified theory for architecture, an endeavor which he initiated in the recent publication 'The Autopoiesis of Architecture'. He has stated multiple reasons for this. He seeks to test the field for consistency, he wants to connect different sub domains and he sees pragmatic benefits in practice. Here he suggests that a unified theory would aid an architect not to contradict himself/herself, it would be required for effective leadership in any large firm and it would be important for the "effective advancement of the discipline as a whole."[128] An important basis for his attempt is the notion of architecture as a network of communications, which he derives from Niklas Luhmann, who argued that once communication is initiated, a bounded social system will be formed. The use of the term autopoiesis also comes from Luhmann, who has borrowed it from biology where it signifies "self-creation" and is intrinsic to self organized systems.[129] Another reference to Luhmann is functional differentiation; an emergent mode of differentiation identified in society today. The function systems identified by Luhmann include the political system, the economic system, the system of science, the education system, the medical system, the system of mass media, the system of religion and the system of art. A key aspect to a function system is that it has its own, unique, societal function that is not part of another function system. Schumacher's contribution to this theory is that architecture as a discipline in fact constitutes another functional system, and he would prefer to change the concept of "the discipline of architecture" to "the self-referentially closed system of architectural communications." Even if a primary concern within architecture is to provide shelter, this is not the essential societal function of architecture since it could just as well be delivered directly by engineers and contractors. Schumacher instead suggests that the essential function of architecture is to frame, order and stabilize social communication, and to continuously adapt and re-order society by providing and innovating the built environment as a framing system of organized and articulated spatial relations. His ultimate aim for developing a unified theory for architecture is that it could guide the future development of the discipline, and he therefore identifies a number of "domains or partial discourses" of contemporary and future relevance.[130]

Together, the idea of Parametricism and the proposal of a unified theory of architecture have continued to make quite a stir within the digital design field as well as in wider fields. A brief recollection of comments and discussions is interesting, since it shows the different views on the notion of parametric design. This in turn may be regarded as a successful turn of events, albeit perhaps not completely expected by Schumacher. He introduced his parametricist manifesto to a wider architectural public under the title 'Let the Style Wars Begin,' and here he suggested that the notion of styles is what brings architectural discourse into the public domain. He further identified the protagonists in this style war to be parametricism and minimalism, and suggested that parametricism offers "a credible, sustainable answer to the drawn out crisis of modernism that resulted in 25 years of stylistic searching." [131]

The on-line version of the article attracted a lot of critical comments, in particular in regards to the issue of sustainability, and whether Schumacher's promise could fulfill needs beyond exclusive architecture. The relation between performance and form is questioned, and the need to address political and social

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122 Gang, Jeanne, 'Fabricating Material Effects: From Robots to Craft Workers' in Kolarevic, Branco and Klinger, Kevin (ed.), *Manufacturing Material Effects, Rethinking Design and Making in Architecture*, Routledge, 2008

123 The manifesto was first oresented and discussed at the Dark Side Club, a critical salon initiated and organized by Robert White to coincide with the 11th Architecture Biennale, Venice 2008. An edited version of the original text is published at: http://www.patrikschumacher.com/Texts/Parametricism%20as%20Style.htm (19/5 2011)

124 Schumacher, Patrik, 'Parametricism – A New Global Style for Architecture and Urban Design,' in *Architectural Design: Digital Cities*, Vol 79, No 4, July/August 2009

125 Schumacher proposes that architectural styles provide the programs with necessary criteria from which the generic codes of utility and beauty can be handled concretely. They provide aesthetic values and formal preferences, as well as performance values with functional bias that together form the basis of the style.
Schumacher, Patrik, *The Autopoiesis of Architecture: A New Framework for Architecture* Vol. 1, Wiley 2011, p.133

126 Ibid. p.275

127 Ibid. p.279

128 Ibid. p.17

129 Luhmann extends the notion of autopoietic systems from biology to non-living systems that self-organize, produce and change their structure and produce other components.
Luhmann, Niklas, 'The Autopoiesis of Social Systems,' in *Journal of Sociocybernetics*, Volume 6, Number 2, Winter 2008, p.85

130 The discourses defined by Schumacher include architecture in relation to 'the identification of urgent societal tasks in the development of global society', 'the advancement of expert functional performance', 'innovation using advanced construction technology', 'the expansion of the formal repertoire', 'aesthetic values', the exploration of digital design tools', 'the advancement of design process rationality', 'wider forms of professional practice', 'popular reception and utilization within society', 'the social and political impact and responsibility' and 'the history of architecture in respect to mentioned discourses'. The first volume covers the five first discourses, which leaves further elaborations on Parametricism to the forthcoming volume.
Schumacher, Patrik, T*he Autopoiesis of Architecture: A New Framework for Architecture* Vol. 1, Wiley 2011, p.18

131 Schumacher, Patrik, 'Patrik Schumacher on parametricism – 'Let the style wars begin,' in *The Architects' Journal*, May 2010 http://www.architectsjournal.co.uk/critics/patrik-schumacher-on-parametricism-let-the-style-wars-begin/5217211.article (5/5 2011)

contexts as part of the research behind the claims is pointed out. While the notion of a parametricist style frequently is dismissed as mislabeled, inappropriate or altogether fundamentally flawed, the attempt to bring the idea of styles into the discussion the introduction of Luhmann's social theory has been regarded as interesting.[132] The manifesto and the proposal for a unified theory of architecture are two partly separate endeavors, but the idea of an 'Autopoiesis of Architecture' is rarely regarded without the view that it heralds parametricism as a style, which is apparent in the following overview of comments.

An anonymous Conditions magazine article regards the manifesto a "mental straitjacket" not suited for the avant garde. Schumacher's statements are seen as stake claiming and positioning, and fascinated by an inner world of architecture that the author defines as a cult of personality, celebrity status, hysterical posturing and self-absorbed formalism. Styles are understood as almost entirely retroactive and as such regarded as a historicist narrative characterized as to simplify, interpret and package complex sets of relations. Beyond critiquing Schumacher's text as a quasi-scientific discussion, the author also objects to the notion that architecture should be "subject to compositional technique to the point of defining itself as an expression of that technique," an overall criticism of the relation between technique and architectural qualities.[133] Peter Buchanan agrees on the application of Luhmann's functional systems to architecture, in that it allows all aspects of architecture (including design practice as well as the built environment) to be regarded as a whole, but suggests that a pure sociologist's view is partial and reductionist, omitting cultural dimensions as well as the physicality of buildings. He also regards that Parametricism, as defined by Schumacher, is a passing phenomena, that remains a subjective style that does not depend on parametric techniques, and does not take into account the "wide range of increased efficiencies, in terms of structure, energy, constructional assembly" that are enabled by parametric modeling.[134] Ingeborg M Rocker argues that the strategies described by Schumacher are in themselves reductive, and simply favor architecture that looks complex over architecture that may be, or function as, complex. "Only if architecture and urbanism are viewed from more than one – currently the formal – vantage point, only if sociopolitical as well as technological-material and organizational aspects are taken into the equation" can parametricism achieve new modes of thinking and designing, where we comprehend the built environment as a part of living ecological systems, she concludes.[135] Marjan Colletti reads 'The Autopoiesis of Architecture' as an "autobiographical theory," in the sense that it emerges from Schumacher's own personal journey within the digital design field, including redefining personal aesthetic sensibilities. With this in mind, he is critical of the "absolutist, fundamentalist language and tone," which he suggests is a main reason to why Schumacher has faced a lot of criticism.[136] Daniel Day responds to Schumacher's definition from a digital expert perspective; he considers the use of the term 'parametric' illadvised and unsuitable, especially in the sense that several different computational terms are presented. To Day, parametric design indicates a particular branch of the digital design field, in which a geometrical model is based on a finite set of parameters (as opposed to generative or emergent processes.[137] Additional objection have been given at a number of public events, as Schumacher has presented his manifesto and proposal for a unified theory of architecture around the world.[138]

The scope here is not to go deeper into Schumacher's proposal of a unified theory, nor to evaluate the relevance of Luhmann's idea of autopoiesis or functional systems in relation to the disciple of architecture. It is instead Schumacher's ambitions to unify the field of digital design as a provocation or a stimulus for discussion that is of relevance. The most distinct rebuttals regard Schumacher's pleas for a collective agenda among practitioners within the digital design field, either due to the vagueness in the way he employs technical terminology as mentioned previously, or due to different views on how to communicate in regards to the digital field. In particular, defining a style through the parametric techniques employed is targeted. One of the most recent exchanges took place in the Fulcrum, the weekly newsletter of the Architectural Association. Mark Foster Gage here introduces the term 'dissensus,' indicating that a state of disagreement is at end – and where "fierce individual experimentation plays out through the chaotic adoption of new technologies & materials, towards even new & surprising architectural ends." Gage believes that architecture is facing a "terrifying obsolescence, produced by the inability to verbally, conceptually or intellectually connect to the world" (by means other than technical arguments).
He argues that architects are pioneers when it comes to formally innovating with technology, and suggests that architects have to learn to value their work in other ways (beyond novelty of tools and processes), more relevant to larger cultural concepts. To him, architecture today can be described as a stable, lasting state of productive disagreement that celebrates individual genius over collective actions, and instead of "forcing new cohesion through ill-fitting manifestos, or attempting to unify work by virtue of tools used to create them," new ideas should be free to go in unexpected directions. Digital design techniques should be applied, but there is no value in talking about them, because Gage regards this as attempts to validate design results through pointing at the process that created them.[139] In Schumacher's response it becomes apparent that he strongly believes that the time of unconstrained experimentation is over, that the avant garde has found a coherent direction, and that parametricism is a response to the needs of society. He admits though, that the performative merits of his proclaimed style must be discussed at the expense of descriptions of the design process, and states that one of the important tasks ahead is to "elaborate the competency to design urban & architectural projects as coherent systems of signification." This entails a need for a new architectural semiology – a "parametric semiology."[140]

The diversity of practices that are part of the digital design field can hardly be distinguished as being part of a formal style, regardless of if their pursuit is based on issues of digital technoogy for the purpose of exploring new formal expression or if they are looking for solutions that increase technical performance of their work. What Schumacher brings is a discourse on overall disciplinary issues, in which he suggests that this could be defined internally. He rightfully identifies re-occurring themes within the digital design field, but when he suggests that such issues can bring an agency that can influence the complete discipline of architecture, he attempts a unification that in turn opposes

many of the individual ambitions. Digital design techniques are within the field employed for very different reasons, and many new modes of design have been a way to differentiate a practice from others. While research in design technologies is shared through conferences and publications, it is in the individual practices intrinsically linked to formal design intentions, either through an integrated design approach in which expression is explored through digital design techniques, or in the form of supportive teams that can rationalize, optimize and evaluate such approaches. To some extent the main driving force of the development of digital design principles – the possibility to design custom solutions to site specific conditions – is opposing any attempt to unify the field. To abandon all discussion on techniques would be a high-risk however; there is an equal importance for continuing technological development, but there may also be other process related issues at stake here. Foster Gage is not alone in disclaiming an interest in a discourse on how processes are conducted, for the sake of the performance of resulting design proposals. What this attitude, and the focus on technological innovation for design and production, does not take into account are the activities around the traditional design process; not what is drawn, and how it is drawn, but all other aspects of the process that are vital for any practice beyond the single, self-oriented individual.

Scope and Agency for Digital Design

While the early years of development within the digital field witnessed numerous practices that motivated their innovation, and their mode of practice, with technological arguments such as the appropriation of tools and techniques from other disciplines (technology transfers) or open ended exploration of the potentials of fabrication technologies, the maturing field is turning to new contexts for exploration. There is still experimentation practice, often from a formal or material perspective, but in parallel there is a renewed interest in deepening the discourse on how a practice can perform successfully within a market, and how new technology can contribute, rather than be the primary motivator. At times previous open ended exploration has led to discoveries that digital technology can operate at a far more strategic level in parallel to the formal design and fabrication modes.

Frequently deployed in other architectural discourses of practice, 'agency' may be seen as the power to act for oneself or for others, a mode of empowerment that suggests independency or the capacity to act with effect. In architecture this has implied practices that act outside of regular power structures, outside of the prevailing construction industry, or through new modes of operation that entails user interaction or political radicalism. A very direct engagement with society is often significant, in opposition of the role of the architect as acting at a distance from actual building (through processes) or from society (by limiting oneself to internal discourse). It has been suggested that this mode of agency signifies a critical practice, as opposed to a projective one, and that the interest in performance in architecture is a move away from theoretical meaning, indirectly alluding to the field of digital design.[141] While practices focusing on agency as a way to enable the public to directly engage in the built environment, the new specialisms required to re-connect the role of the architect with the act of building may in turn operate against this. Alternate modes of production, that could entail an architecture that is more engaging, more expressive, and more local and may provide new ways for the public to interact, would require a higher degree of professionalism.

The fact that digital design methods employed suggest an empowerment of the profession, in regards to a more direct involvement in construction, suggests the opposite however, and the inclusion of scope to provide meaning further supports this. As new production technologies are directly interfacing with design software, and previous envisioned spatial and tectonic concepts are gradually being transformed into built work, it has been suggested that a new era of digital architectural craftsmanship is being established.[142]

In a way, the infiltration of the building industry with new architectural and aesthetic ambitions is agency at work already, attempting to induce new qualities in the built environment from within. Perhaps the formal and procedural strategies that have been developed over the past 15 years could be seen as positioning strategies, with a continuous pursuit of newness, but lacking in scope.

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132 See for example Parnell, Steve, 'The style wars continue' in *The Architects' Journal*, February 2011, http://www.architectsjournal.co.uk/critics/the-style-war-continues/8611435.article (15/11 2011)

133 The article was published anonymously under the pseudonym A Teem.
Teem, A., 'A Critique of the "Parametricist" Text,' in *Conditions #3 Glamorous compromise*, December 2009

134 Buchanan, Peter, 'The Autopoiesis of Architecture dissected, discussed and decoded,' in *The Architectural Review*, March 2011 http://www.architectural-review.com/essays/the-autopoiesis-of-architecture-dissected-discussed-and-decoded/8612164.article (14/11 2011)

135 Rocker, M. Ingeborg, 'Apropos Parametricism: If, In What Style Should We Build?,' in *Log 21*, Winter 2011, Anyone Corporation, 2011

136 Colletti, Marjan, 'Turbulence Ahead,' on http://marjan-colletti.blogspot.com/2000/09/turbulences-ahead-book-review.html (14/11 2011)

137 This text was posted in Davis's personal blog. In the exchange of comments that followed in Day´s initial statement, Schumacher returns and explains his use of the terminology as operating on a "broader level of abstraction" in order to define a style as a "vehicle to galvanize a movement and to reassert its importance."
Davis, Daniel, 'Patrik Schumacher – Parametricism,' published 2010.09.25 on http://www.nzarchitecture.com/blog/index.php/2010/09/25/patrik-schumacher-parametricism/ (14/11 2011)

138 Schumacher himself organized a debate at the Architectural Association in the spring of 2011, to which several prominent practitioners and theorists were invited to discuss his recent book. This session was facilitated as conversations between Patrik Schumacher and a number of invited guests. While the topic was "Probing the Autopoiesis of Architecture", the conversations often converged on the idea of parametricism. See for example comments by Eric Owen Moss: http://www.aaschool.ac.uk//VIDEO/lecture.php?ID=1505, Jeffrey Kipnis: http://www.aaschool.ac.uk//VIDEO/lecture.php?ID=1517 and Mark Cousins: http://www.aaschool.ac.uk//VIDEO/lecture.php?ID=1506 (31/7 2011)

139 Foster Gage, Mark, 'Project Mayhem,' in *Fulcrum* issue 18, Architectural Association, June 2011 http://fulcrum.aaschool.ac.uk/pdf/fulcrum18_080611_dissensus.pdf (5/8 2011)

140 Schumacher, Patrik, 'Convergence versus Fragmentation,' in *Fulcrum* issue 19, Architectural Association, June 2011 http://fulcrum.aaschool.ac.uk/pdf/fulcrum19_100611_convergence.pdf (5/8 2011)

141 Isabelle Doucet and Kenny Cupers (ed.), 'Agency in Architecture: Reframing Criticality in Theory and Practice,' *Footprint, Delft School of Design Journal* 4, 2009 http://www.footprintjournal.org (7/3 2010)

142 Branco Kolarevic and Kevin Klinger (ed.), *Manufacturing Material Effects, Rethinking Design and Making in Architecture*, Routledge, 2008

The idea of the provisional has been introduced as a working term for the content and positioning of a number of practices that have made a transition from a fringe experimental context to what could be considered the mainstream, as they are presented in the publication with the same name[143] While operating in quite different ways, the inventors of the term have identified similarities in their objectives in that they share an opportunistic, pragmatic, strategic and optimistic approach to the discipline. They are considered to reformulate the idea of the critical practice with an aim of bridging between theory and building, and transform digital design and fabrication into a craft deployable in commercial projects. They look for new opportunities within the market today, and as they do so they negotiate and synthesize existing systems and emergent technologies. This may entail an improved control over project management and execution, and new roles for the architect beyond the traditional, as in the case of SHoP Architects who often share the financial risks in projects they conduct.

These practices are performing within the existing system of the industry, but look for alternate routes and opportunities. As Marc Tsurumaki, partner of featured practice Lewis.Tsurumaki. Lewis, states in his contributing essay: "By maneuvering tactically within these operational boundaries, architects can tease out the latencies of normative configurations, generating new social and spatial possibilities within the logics given." [144] This could entail finding new niches such as the product and system development of Front Inc., turning into a software and management provider such as Gehry Technologies, or integrating consultancy services traditionally belonging elsewhere into an architectural practice exemplified by SHoP. As these alternate routes are taken, the internal organization of a practice needs to adapt to new conditions; the employment of new specialists requires routines for collaboration, new design tasks may require material or fabrication research and as digital toolmakers architects may have to make the transition from laymen programmers to professional software developers. As these routes are becoming familiar territory, these practices hopefully also change the conditions they face through their mode of practice, as a direct influence on the industry as well as through contribution to a discourse on practice.

As means of empowerment, a practice needs to achieve agency in order to understand the conditions faced, and to interact and affect those conditions. Especially in a time when culture and market is in flux, this interaction needs to be a natural mode of operation. Michael Speaks notion of design intelligence as the capture of intelligence chatter or "little truths" denotes a practice able to identify signs of new conditions, and as able to respond to them.[145] The increasing knowledge of production technologies may give new conduits into the industry, but that knowledge is often limited to the use of machines to produce desired results. As the business models of architectural production are changing, an engagement in higher level business processes can provide new solutions for processes and proposals alike.

The internal organization and processes of a practice is fundamental for an innovative approach, and again technology may very well support this, but is not the answer in itself. As architect come business strategist Paul Nakazawa suggests, the key intent within a practice lies in the intersections between design practice, internal business development and administrative organizational systems. An adaptive practice needs not only to come up with new design strategies to remain a viable actor, it may also need to restructure itself from within, which ultimately affects the offer given to any market (commercial or not), potentially rebranding both identity and mode of operation.[146]

Prototypical approaches

The notion of the prototype has previously been discussed as an object, system or set of rules, and several experimental design projects have been presented in which series of prototypes have been fundamental to the conceptual as well as formal design development. In the case of the projects developed within Krets, innovation was used to designate a design process of exploration, not only of formal outcome, but also of purpose – an innovative approach based on digital and physical prototypes [Contexts I: p.24, p.45, p.48 | Projects I: p.12].

In this chapter, proposals for more formalized processes in digital design have been brought up, as part of the current reformation. Different discourses affiliated to the digital design field have been discussed, and potential contradictions in concepts such as the idea of performance in architecture and in digital design have been reviewed. Overall, the digital design field has been evolving through interests in the performance of design techniques, and the alternate architectural performance such design techniques may enable. The recent debates on styles and common grounds have shown that there is an interest in addressing these issues, but there is no consensus or a belief that there need to be one.

As similar techniques are contextualized in architectural design projects, either as comprehensive student projects, or as strategic elements in projects in practice, the idea of the prototype can be expanded. While individual prototypes to certain extents still can be identified in these design developments, a more interesting aspect is perhaps the effects of the employment of digital techniques on an overall design process. It requires a shifted perspective, a slightly different approach – a prototypical approach, in the sense that certain key elements may be kept open until a very late stage, while others requires an earlier establishment of design principles. In order for digital design modes to achieve agency within an overall design process, and for architecture developed through digital means to perform in the multiple roles discussed previously, there is a need to understand the processes that connect different modes of design. In parallel, the suggested use of digital design tropes substitutes a vessel that can combine formal approaches with performative qualities in regards to both technical aspects and aesthetic experiential effect. These tropes have been regarded as potential instruments for disseminating design knowledge in regards to techniques in a way that rapidly has a global effect, but can also be differentiated from any claim to stylistic hedgemony or typological prescription. They are for the purposes of this thesis regarded as prototypes in themselves, and catalysts that may enable multiple practices to share endeavors in architectural exploration, ultimately supporting a proto-

typical approach within a digital design field seeping into general practice. In the following chapters, two additional outlines will be conveyed. With shared knowledge within the field, and continued development that perhaps could be regarded as converging, at least in terms of a general interest in digital fabrication, this thesis proposes that a renewed speculative mode is relevant for the field. On the other hand, the current reformations are still focused on the act of design, regardless if seen from a process view (in terms of design tools) or a performance view (in terms of technical and architectural performance). The third chapter of the thesis proposes the need for a strategic perspective, in particular in regards to how digital design activities are facilitated in general practice.

Summary:

- Practices that have been in the forefront of the digital design field are frequently also engaged in teaching and research, through which experimental techniques have been pursued.

- The digital design field has also led to the emergence of new specialists, and new forms of practice, and through these, new roles for architects follow.

- While many of these practices share techniques and to certain extents conceptual frameworks, and attempts have been made to formulate common agendas in order to reform the discipline of architecture, such endeavors meet resistance from within. This suggests that modes of continuous reformations lie at the core of such practices, and that the pursuit of new forms of practice resists attempts to formalize agendas beyond the techniques themselves.

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143 Kedan, Elite, et al., (eds.), *Provisional – Emerging Modes of Architectural Practice USA*, Princeton Architectural Press, 2010

144 Ibid. p.25

145 Michael Speaks presents a number of practices he considers to employ this notion in a series of interviews titled 'Design Intelligence,' *A+U* (2002:12 – 2003:12)

146 Paul Nakazawa in two lectures at Architectural Association, 'The Sorcerer's Shrink,' 14 November 2008 and 'Next and Again: Progress and Recurrence,' 21 January 2010

Informed Speculations

> *"That's really what Science Fiction is all about, you know: the big reality that pervades the real world we live in: the reality change. Science fiction is the very literature of change. In fact, it is the only such literature we have."*

Frederik Pohl, *Pohlemic*, 1992[1]

Architectural Experimentation

The formation of the digital design field over the past 20 years has been characterized by an open ended and speculative approach. As discussed in the previous chapters, a subsequent reformation of the field has seen attempts to formalize digital design procedures, shifts in discourse, a general interest in the design outcome in terms of its architectural as well as technical performance and discussions on its influence on architectural practice and discipline. If these aspirations are regarded as efforts to consolidate the field within architectural practice, the industry, society and culture, are there still trajectories that can continue to promote an experimental approach? Can we find a useful terminology for such endeavors? Before considering the contemporary situation and the near future, it is worth to revisit speculative modes in earlier experimental practice. For the purposes of the continued discussion three historical examples have been chosen, all emerging from the architectural scene of the 1960s. The objective is not to go deeper into the ideologies of these practices, but rather examine their modes of practice, and the media they employed.

Constant Nieuwenhuys initially explored his visionary 'New Babylon' through models, which also were used in exhibitions and photographed for lectures. His decision to work materially with the notions of 'unitary urbanism' set him aside from his colleagues in the Situationist International movement (SI).[2] In particular Guy Debord disapproved of the pragmatic approach to what he considered contradictory to the other strong concept of the movement; 'détournemant,' the act of reusing existing work through a subversive approach. Constant's initial maquettes were regarded as something in between sculpture and architectural model, but later he moved into drawings as a way to contextualize his visualizations of New Babylon at a geographical scale, and within an architectural culture. Growing from his earlier SI involvement, the freedom of the citizens with labor obsolete, the elevated structures of New Babylon would be design purely for differentiation in ambience, and the creation of situations and meetings between its occupants.

To Archigram, the drawing itself was a reaction to what they regarded to be a culture of policy making in schools and offices in the early 1960s, and the heavy sampling of popular culture further enriched the graphical quality of their work.[3]

The Archigram members found architectural potential also in other industrial fields, turned into means of their arguments through representation rather than full technology transfer. Principles of flow intrinsic to system design were equally transformed into their concepts of dynamic movement and reconfigurable structures. Their designs were not thought of as final solutions; they would rather manage change, and explore the paradox between control and choice. Responsive mechanisms would provide freedom to individual people, and the logic of optimization, standardization and economics would control the supplies necessary for this freedom. The magazine Archigram, published in nine full issues and a complementary half issue from 1961 to 1974, collected the work of the team members, student work as well as work of others deemed to be related. In this way, it became communicative platform, and a framework, for speculations primarily through the mode of drawing. With issue four, the ZOOM issue published in 1964, they gained international reputation, and unintentionally the comic book illustrations gave the group fame for being comic book architects. The issue included an essay on science fiction and science fact, written by Warren Chalk (illustrated by science fiction comics), who suggests that science fiction visions in popular culture can inspire in the search for "radical valid images of cities." [4]

Superstudio operated in a double mode, through regular commissions as well as provocative projects set to disrupt the status of objects, to eliminate the accumulation of the formal structures of powers in the city, and to end specialized and repetitive work seen as foreign to the nature of man.[5] Their histograms of architecture were prepared as catalogues of "three-dimensional, non-continuous diagrams," and were employed in the design of numerous objects and pieces of furniture. The 'continuous monument' employed a similar grid and was regarded as a form of architecture consisting of one single environment, rendered uniform through technology, and presented through collages situated in various locations around the world. The 'Twelve Cautionary Tales for Christmas: Premonitions of the Mystical Rebirth of Urbanism" project featured twelve descriptions of "ideal" cities in which technology provides control mechanisms that makes each city an extremely optimized for its individual purpose such as managing reproduction of its citizens, providing complete freedom or optimizing the production of goods. The 'Five Fundamental Acts' project was conceived as a series of films to be shown on TV, in exhibitions or other venues, centered on the relationships

between architecture and the acts of human life. In their experimental and radical role, Superstudio aimed for a revolution in architecture (rather than a revolution with architecture), but many of their projects were aimed at provoking discussion about the cultural and social systems and the models of behavior that comes with them.

Technology plays a role in all three practices. Archigram and Constant shared the interest and belief in new technology as a way to liberate people. Inspired by the discourse of cybernetics they also envisioned new emerging networks, forecasting the internet through physical systems. After leaving SI, Constant was operating on his own, developing his notion of New Babylon over a number of years, and his artistic style in modeling, drawing and painting gives New Babylon much of its character. The Archigram team members were inclusive and built their architectural culture also on the works of others, such as Konrad Wachsmann's development of space frame systems, Cedric Price's work on the Fun Palace or Buckminster Fuller's geodesic domes, all featured in the Archigram magazine at different times. To Superstudio, technology played an important role in their creation of 'negative utopias' such as in the Twelve Cautionary Tales and in the last phase of activity within the practice they moved into academia, committed to study 'extra-urban material cultures,' such as the disappearing Italian peasant traditions. To Archigram, advanced technological systems would provide freedom to the individual. To Constant this freedom would set the conditions of a new society. To Superstudio, the target was to deliver a continuous critique of architecture as a discipline, of normative cultural values, and of society. With different objectives, the three practices still operated in a similar space between architecture, art and popular culture. Their momentum was built on the development of a practice culture, based on the integration of ideas, theories and representations. Their audience was primarily within the architectural profession, through work disseminated in publications, lectures and exhibitions, with alternate routes through the art scene or to certain extents popular culture. Their use of technology could be described as narrative and speculative, integrated in the envisioned design work. Their main mode of practice was to provide alternate versions of reality, and of practice, even though their motivations for doing so differed.

In an analogue way, the objective of science fiction as a literature genre in general is to produce an alternate version of reality, often but not always projected into the future. The SF writer must not only provide an interesting hypothesis, but also accomplish a balance between the new (or fantastic), and the recognizable (and plausible). Science fiction can also be related to utopian writing, in fact regarded by Fredric Jameson to be a socio-economic sub-genre of SF, in that it is devoted to the imagination of alternative social and economic forms.[6] He suggests that the SF writer is faced with a task associated with utopia by default. As the writer of criminal stories needs to invent a crime, the writer must create an entire universe, a "double inscription" in which the first imagined context must be regarded as fact in the narration. The literary field of science fiction does however cover a multitude of utopian ideas, rather than a single vision. He also argues that the most characteristic science fiction does not seriously try to imagine the "real" future of society; rather it provides multiple futures that prepare the reader for something yet to come by transforming our own present to the determinate past.[7]

Direct relations to science fiction can be traced in the three examples of 1960s radical architecture practices. Constant himself considered his plans and models architectural science fiction, in that the recreational pursuits and new situations he was aiming for would affect any idea of urban study in a considerable manner.[8] This was in response to the SI notion of psychogreography, defined as the study of the specific effects of the environment, consciously organized or not, on the emotions and behavior of individuals. Asger Jörn, another SI member, has been credited for the statement that psychogrography can be regarded as the science fiction of urbanism.[9] Archigram directly refers to science fiction as a cultural phenomenon, set against science fact but suggesting that many innovative ideas of the genre (at the time) were not far from reality, and relating the ideas produced by science fiction comic artists with "material, a function or a justifiable architectural gesture." [10] While Superstudio did not directly refer to science fiction in reference to their work, Kenneth Frampton compared their visions of the continuous monument to a "science fiction landscape, in which nature had been rendered benevolent," not to be interpreted as a monumental form in the existing landscape, but rather a phantom projection across an altered spatial-temporal continuum.[11] In the case of Constant and the SI, the science fiction analogy represents dynamic aspects of performance, combining affective aspect with the idea of responsive as well as differentiated zones of New Babylon. For Archigram, the relation is to representations of new technological and formal potentials, but it could also be related to the fictional worlds of ideas forming through the Archigram magazine. In Superstudio, the representational aspect is apparent, but in works such as the speculative cities of the twelve Cautionary Tales, Superstudio member Piero Frassinelli authors science fiction texts, expanding and amplifying on the critical view of technological modes of control.

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1 Allegedly a citation of Frederik George Pohl, science fiction writer, editor and fan : http://fritzfreiheit.com/wiki/Quotes_about_the_definition_of_science_fiction (3/1 2012)
2 De Zegher, Catherine and Wigley, Mark, *The Activist Drawing: Retracing Situationist Architectures from Constant's New Babylon to Beyond*, The MIT Press, 2001 and Van Schaik, Martin & Mácel, Otakar, *Exit utopia; Architectural Provocations 1956 – 76*, Prestel, 2005
3 Sandler, Simon, *Archigram: Architecture without Architecture*, the MIT Press, 2005
4 For a presentation of all Archigram issues by Dennis Crompton see: The Archigram Archival Project, University of Westminster. http://archigram.westminster.ac.uk/ (2/1 2012)
5 Lang, Peter & Menking, William, *Superstudio: Life Without Objects*, Skira Editore S.p.A, 2003
6 Jameson, Fredric, *Archaeologies of the Future: the Desire Called Utopia and other Science Fictions*, Verso 2005, p. Xiv.
7 Jameson, Fredric, 'Progress Versus Utopia; or, Can We Imagine the Future, *Science Fiction Studies #27*, Volume 9, Part 2, 1982
8 Constant, 'The Great Game to Come,' in *Potlatch # 30*, 1957 Translation available on-line at: http://www.cddc.vt.edu/sionline/si/greatgame.html (2/1 2012)
9 Khatib, Abdelhafid, 'Attempt at a Psychogeographical description of Les Halles,' in *Internationale Situationniste #2*, 1959 Translation available on-line at: http://www.cddc.vt.edu/sionline/si/leshalles.html (2/1 2012)
10 *Archigram # 4*, 1964 Available online at: http://archigram.westminster.ac.uk (2/1 2012)
11 Frampton, Kenneth cited in Lang, Peter & Menking, William, *Superstudio: Life Without Objects*, Skira Editore S.p.A, 2003

Summary:

- Direct and indirect influences from science fiction can be traced within the experimental architecture scene of the 1960s, but is particularly relevant in the way speculations on future potentials of technology was employed for a critical discourse on the present, as dystopic scenarios, disciplinary critique or positive arguments for the potential role of architecture in culture and society.

- The speculative mode of these practices was intrinsically tied into their mode of working in terms of representation; the aesthetic qualities of their work contributed immensely to the reception of their work, but between the practices these qualities were very different.

Studies on Speculation

A number of concepts have been defined in order to categorize different modes of speculation within science fiction, and the purpose of this chapter is to explore a selection of these concepts, discuss their potential for the experimental field of architecture in general, and for the digital design field in particular. Science fiction studies as a field for theorizing science fiction (referred to as SF from here), is to a large extent obsessed with definitions of SF in relation to "main stream" literature (and the pros and cons of being a genre) and the distinction between SF and the literary genre of fantasy. This often also entails making distinctions between what has been defined as pulp fiction, a heritage from Hugo Gernsback's Amazing Stories Journal [12], and other bodies of work that has a lineage from a wider tradition of writing. In this thesis, science fiction has been regarded as a literary field that makes informed projections, or 'extrapolations,' into possible futures or alternate presents, based on technological, biological or other changes that influence our society in a projective way. The notion of extrapolation will be informed by additional concepts and terms from science fiction studies, but the discussion on the delimitations of the genre is mostly disregarded. Likewise, SF is endlessly divided into sub-genres that further categorize different tropes, such as Space Opera (adventures in space), Apocalyptic (end of civilization), Alternate History (based in alternative events that make history turn out differently) or Cyberpunk (near future often dystopic scenarios based on new technology and changes in societal control). The only differentiation that is discussed here is the distinctions between Hard and Soft science SF, and how those characterizations are valuable for comparisons with innovation and speculation in the digital design field of architecture.

Furthermore, the relation between architecture and science fiction film has a long tradition, with visionary examples such as 'Metropolis' (Fritz Lang, 1927), 'Things to come' (William Cameron Menzies, 1936, adapted from H.G. Wells's 'The Shape of Things to Come,' 1933), 'Blade Runner' (Ridley Scott, 1982, loosely based on Philip K. Dick's 'Do Android Dream of Electric Sheep?,' 1968) and 'Inception' (Christian Nolan, 2010). It is not uncommon for architects to cite SF films as important inspiration, and in reverse many films tap into recent trends in architecture, but for the purpose of this thesis, science fiction film is not covered. The interest here lies on a number of concepts that surpass the visual, and focus therefore lies on science fiction as written text, but the continued discussion will suggest that these concepts can also be relevant in the representational and conceptual modes inherent to the digital design discourse in architecture.

Concepts and Themes in Science Fiction

The terms sampled from science fiction are discussed in many different sources, but belong to SF studies and are not necessarily instrumental techniques employed by SF authors. Soft SF is typically more concerned with character and society and is not as tied into scientific or engineering innovations. Philip K. Dick can be seen as a representative who used features based on psychology and perception in works like 'Do Androids Dream of Electric Sheep?' (1968)[13] and 'A Scanner Darkly' (1977)[14]. Hard SF is signified by a strong sense of logic, in which the reader can understand the reasons why the proposed reality potentially could exist, primarily through references to innovation in sciences such as chemistry, biology, physics and engineering. These sub genres are more often than not overlapping and should be considered interlacing themes.

Science fiction critic Darko Suvin has introduced the terms 'novum' and 'cognitive estrangement' to denote this exploration of an unknown and unfamiliar territory, with the provision of a logical explanation of its relation to our own present. The cognitive aspect allows the reader to understand the reasons behind the proposed reality, often through links to his or her own world. Estrangement indicates a subject that can be recognized, yet seem unfamiliar, and substitutes a formal framework of the genre. In this way, Suvin suggests that it implies a reflection on reality itself, and also somewhat disarms the potential overwhelming from aesthetic or artistic effects, perhaps even more so apparent in film.[15] An emphasis is put on the rigor of research and implementation of science, as well as the relationship between the narrative and the scientific content. Technology normally plays a strong part in these stories, and the environment is often based on speculations within science, as in the classic novel 'Ringworld' by Larry Niven (1970), introducing variations of the Dyson Sphere.[16]

In this way, cognitive estrangement induces an affect in the reader, through the successful integration of alienated and a familiar aspects, which could regard technology, but also other conditions such as social behavior, political structures and natural law. Science fiction is, according to Suvin, determined by the dialectic between the two terms, in which cognition provides means to do a critical interrogation of an alternate fictional world. Since there often are no exact measures for such a critical interrogation (especially in work that is not precisely based on scientific predictions or well founded in a scientific understanding of behavior), one might instead use the term 'cognition effect'. This entails that the critical approach is not necessarily based on scientific theory, instead it is part of the attitude in the text itself, and the way it proposes a plausible narrative that explores the speculation.[17] Cognitive estrangement regards the

aesthetic effects of works of SF, and as such can be seen as a generic term of speculative fiction.

The act of projecting into the future, or into alternate realities, is at a general level defined as 'extrapolation'.[18] Suvin traces this idea to the early history of SF, at a time when the genre was characterized by a proto-scientific and naive social critique, to be further refined towards the late 20th century when SF became a warning, diagnose, or mapping of possible alternatives. He has also suggested that consistent extrapolation becomes an important aesthetic factor, depending on its rigor and the use of analogy and reference. Analogies may refer to how the behavior of characters in the story, or the proposed changes within the depicted societies, are recognizable and plausible. References signify the rigor of research into technologies or hard/soft sciences as important foundations for the speculation, and crucial for relevant extrapolations.[19] The subject matter for extrapolation within SF can vary, ranging from the fields of science, technology and psychology, to environmental conditions or political ideologies. The amount of change suggested through extrapolation often involves paradigm shifts in one or more fields, as a result of the narrative, or as a given in the proposed alternate world. This requires a certain amount of hypothetical ideas that defy contemporary theory, in a way that goes beyond any scientific approach to extrapolation. With an orientation towards examining possible changes in society, seeking to establish conceptual bridges between the reality we know and fictional worlds, in a way that intellectually and aesthetically is distanced from the theories on which the extrapolations are based.[20] In these estranged worlds, exploration is explored through the narrative, but the performance as fiction depends on the reader's capacity to believe that the suggested scenario is plausible. David N. Samuelson has suggested that extrapolation is only one of several 'extension bridges'; instruments that enable a transgression of what the reader regards as reality.[21] 'Speculation' is by Samuelson used specifically as a term that indicates an inverted extrapolation, in the formation of a new theory to explain the possibility of something seen as highly unlikely. In this mode of post-rationalizing the author would describe the conditions that provide logic to unlikely phenomena. At the other end, 'transformations' are rigorous extrapolations from scientific theories that may seem too distanced from the society of today, in that they depend on paradigm shifts in science that require that knowledge we take for granted needs to be reconsidered.

Samuelson further proposes 'forecasting' in SF as an extrapolation of historical processes often based on a combination of hard and soft sciences, and indicates that it is an important method for extrapolation.[22] He distinguishes it from 'world-building' that according to him indicates the extension of scientific processes, or ultimately reconsidering scientific truths of today. Samuelson suggests that SF is supported by three "philosophical principles," empiricism, determinism and relativism, and two operating procedures; prediction and control. In SF these principles are often subject to exaggeration or inversion. These "model making processes" allows the distortion of realities for the purpose of the narrative.[23]

While the goal of scientific forecasting is to present likely predictions of the future, the SF equivalent is to present plausible predictions that allow the exploration of new ideas while being acceptable by the audience. In addition, the writer is of course at liberty to exaggerate or to invert any likely event, not only in order to make things more plausible, but to set up the context for the purposes of his or her narrative. This implies that there is purpose to the story, and that the writer intentionally may be directing the situations towards a scenario in which a particular series of events can be played out. In essence, writing becomes propositional, if not as an absolute truth or even a likely event, at least as a provocative thought experiment.

Fictional References

In order to identify conceptual tropes within Science Fiction that may be relevant in searching for the potential of a framework for speculation in digital design, a number of works are included in the overview below. The selection is in no way comprehensive, and has been made in regards to issues present in each work that invites further discussion in this context, and as examples through which the previously presented concepts and themes become manifest. The defined categories are not meant to imply that the particular mode of extrapolation is exclusive. The issues explored may also go deep into other areas; technological extra-

12 Hugo Gernsback founded *Amazing Stories* in 1926, and it was published continuously by different publisher until 2006.

13 The setting for the book is a world suffering from radiation poisoning, where animals are rare. The dependence on synthetic animals (as pets) and androids makes empathy a unique human trait, and a way to identify an android.

14 Set in a near future where drug cultures flourish, the book dwells on psychological changes and drug induced behavior, as well as issues of identity and deception, as the main character is both a drug user and an undercover agent. Technology is present in the form of scrambler suits that allows the wearer to remain anonymous.

15 The term estrangement is borrowed from Bertolt Brecht's "Verfremdungseffekt," a representation that can be recognized but yet seem unfamiliar. Suvin, Darko, 'SF and the Genological Jungle,' in Gunn, James and Candelaria, Matthew (ed.), *Speculations on speculations: theories of science fiction*, Scarecrow press Inc., 2005

16 In Ringworld the setting for the narrative is a particular kind of the Dyson Sphere, originally described by Freeman Dyson in 1959 as a system of orbiting satellites that completely encompass a star and capture most of its energy output.

17 Freedman, Carl, *Critical Theory and Science Fiction*, Weslayan University Press, 2000

18 In mathematics, extrapolation is the process of creating new data based on known datasets. It could be applied in forecasting and predictions of issues such as population growth, economical trends or environmental changes. Early use of the term included the calculations for aiming gunfire at moving targets, as conducted by mathematician Norbert Wiener during World War II. "Norbert Wiener." *Encyclopædia Britannica Online Academic Edition*, Encyclopædia Britannica Inc., 2012. http://www.britannica.com/EBchecked/topic/643306/Norbert-Wiener (3/12 2012)

19 Suvin, Darko, 'SF and the Genological Jungle,' in Gunn, James and Candelaria, Matthew (ed.), *Speculations on speculations: theories of science fiction*, Scarecrow press Inc., 2005

20 Samuelson, David N., 'Modes of Extrapolation: The Formulas of Hard SF,' in *Science Fiction Studies #60*, July 1993

21 Ibid.

22 Forecasting as a technique is applied in many different fields, including economy, politics, sales, supply chain management and of course meteorology. It involves making statements on the outcome of events not yet observed, and typically relies on statistical methods. Risk and uncertainty are central, and it´s common practice to indicate the degree of uncertainty in any forecast. A prediction typically suggests one specific outcome, while a forecast may include a number of potential scenarios. A common outcome is the scenario, used to model several alternate versions of forecasts that acknowledge indeterminism.

23 Samuelson, David N., 'Modes of Extrapolation: The Formulas of Hard SF,' in *Science Fiction Studies #60*, July 1993

polation may very well result in a narrative that explores cultural, social and political issues. The categories are also a product of this thesis; they are structured around identified traits that through their characteristics relate to their conception in regards to established worlds and forecasted situations as frameworks for the narrative. This is intended as a means to locate applicable principles for modes in design. Based on extrapolations of the science and technology of today, for the creation of worlds where technological or scientific advances have a strong influence on life. In some cases, technological inventions may even take on the role of characters, or be the basis for completely new habitats. Extrapolations that may originate in science or academic disciplines but are recombining them in innovative ways, may be regarded as a form of conceptual extrapolation. In these examples, the cognitive aspects of the speculation cannot be traced to any progression of current logic, and therefore takes on a very conceptual role in the created worlds. They become hypotheses that can only be "validated" through their internal logics, as presented by the author, similar to Samuelson's specific use of the term 'speculation'. There are also examples of how architecture and alternate spatial conceptions become integral to the narrative, as a framework for a speculative narrative on the impact of new technologies, or even being the speculative subject matter itself. This may entail a fascination of spatial anomalies and complex geometries, explorations of extremely artificial environments or alternate use of otherwise very ordinary urban conditions.

"The point is not to make another Earth. Not another Alaska or Tibet, not a Vermont nor a Venice, not even an Antarctica. The point is to make something new and strange, something Martian." [24]

In the field of science fiction the dystopia of failed ecosystems and extreme pollution is more than common, but often they merely provide a setting that is alien to our own. In SF featuring extrapolation on changes in environment, these issues instead take on an active part, and become central to the narrative. They may also reject the inevitability of machine futures where technology is the primary answer to all issues, or suggest the development of completely new ecosystem. The science and technology of space travel, genetics and biology constitutes the basis for extrapolation for Kim Stanley Robinson in his trilogy on the colonization of Mars [Projects II: p.166].

The scientific and environmental issues in the Mars trilogy are intrinsically linked to the social and political development, or as Fredric Jameson suggests in his discussion on Robinson's work: *"... we need to insist on the way in which any first scientific reading of the Mars trilogy must eventually develop into a second allegorical one, in which the hard SF content stands revealed as socio-political – that is to say, as utopian."* [25] The utopian aspects identified by Jameson are not the political events as such, but rather the new premises previously unexplored that Mars in conjunction with the terraforming technologies offer. The "clean slate" of a new planet seems to resist the establishment of old political ideologies, and the narrative is more depending on the new conditions of the terraforming project, and the way the individual characters are developing in this new world. The different political solutions are played out against each other, staging "an implicit debate with the objections and ideological and political prejudices of its readers." [26] The work of Robinson can be regarded as world building in a literal sense, as well as in the meaning suggested by Samuelson. The fictional Mars in effect becomes a laboratory for ideologies and individual interests, as triggered the extrapolation towards new technological opportunities as well as the forecasting of environmental changes, and in extension the red planet becomes the battleground for different utopian ideologies.

While restraints and conditions that follow the logic of the cognitive are common in SF, there are also opportunities gained when the extrapolation moves beyond such thresholds, setting a new framework for political and social agendas. Scottish writer Iain M. Banks has developed and explored a world based on the idea of a post-scarcity society through his novels in his Culture series, a world of infinite resources [Projects II: p.166]. In this civilization of thirty trillion people spanning the galaxy, energy and matter is available in abundance, defusing capitalism through advances in technology.

"The ship was bored. It was also aware of a continuingundercurrent of fear; a real emotion that it was by turns annoyed at, ashamed of and indifferent to, according to its mood." [27]

The most important aspect of technology introduced in the Culture novels is based on Artificial Intelligence (AI), considered by Banks to be an inevitable feature in an advanced society. The most important speculation in the creation of the Culture deals with territory; the fact that this civilization inhabits space (and prefers space before a life on a planet), and the technological principles that Banks invents to allow such a scenario further emphasizes this. Territory affects resources, living space, communication and how societies are formed, and Banks thereby suggests that our current power systems cannot survive in space, and further argues that *"beyond a certain technological level a degree of anarchy is arguably inevitable and anyway preferable."* [28] Survival in space depends on self-sufficiency, and each artificial colony is so vulnerable that a hostile attack would destroy any value for the protagonist. Technology enables freedom, but also brings new complexity through interaction between AIs and humans, or the biological evolution enhanced with genetic manipulation; the Culture human lives up to four centuries, has an optimized immune system, can control autonomic body systems including the change of sex and can administer a number of useful drugs through altered glands.

In many ways the Culture is portrayed as a successful combination of anarchy and liberalism; it is committed to the autonomy of all sentient beings and the abundance of energy and goods, as well as the absence of an economic system all together, removes the temptation to misuse power. The narrative is often propelled forward through conversations, including Minds communicating with each other at an immensely high speed due to their processing power, allowing for a lot of reasoning and heated arguments over microseconds. This becomes an important aesthetic aspect of the Culture novels, as are the depictions of their different personality traits. Throughout the series, the nar-

rative explores the often dramatic events that Banks suggest would be inevitable even in an interstellar liberal utopia, often facilitated through the interactions of the only governing body, the 'Contact section,' concerned with discovering, cataloguing, investigating, evaluating and interacting with other civilizations. In this way Banks adds interventions and problems from the outside to probe the capacity of his imagined Culture, bringing about a discussion on the plausibility of such a perfect liberal Utopia. As the Culture considers any civilization too far from their ideological principles a potential threat, these conflicts often lead to offensive action. In a literary review intensely criticized within the fandom of Culture, English Professor Alan Jacobs even makes an analogy between the actions of the Culture and US foreign policy under the recent Bush administration, suggesting that the Culture is in fact "neoconservatism on the greatest imaginable scale." [29] The difference is perhaps, Jacobs suggests, that President Bush is not a Mind.

Banks' creation of the Culture can be regarded to operate through a mode of 'speculation' as defined by Samuelson, exploring the territorial effects of a life in deep space. Banks speculation and concurrent analysis and establishment of a logic system tounderpin this can be identified in his view on the liberal political systems of the Culture, but also the issues that arises from this. The use of Artificial Intelligence is based on extrapolations through which AIs achieve sentience, and are regarded as important as any living person. Through the narrative, the Minds are understood as very individual and sometimes eccentric characters whose objective the reader can only partially fathom. Similarly, the freedom achieved through biological advancement is based on extrapolation of current knowledge in genetic engineering, and the author's proposal for how this may affect humanity includes societal structures as well as personal relations. The fact that individual characters may also object to the libertarian society, is reflected in the resulting conflicts that arise throughout the series.

The framework for speculation can also be based on new knowledge, and the political ramifications of new scientific discoveries. In Isaac Asimov's Foundation series, the mathematician Hari Seldon develops a new branch of mathematics known as psychohistory, related to mathematical sociology [Projects II: p.166]. Set in a distant future, humanity thrives in a galactic empire spanning the Milky Way, but Seldon's new science, a predictive science based on mass behavior, indicates that the empire is about to fall and be followed by a thirty thousand year long dark age.

"Finally, Seldon stopped. "This is Trantor three centuries from now. How do you interpret that? Eh?" He put his head to one side and waited." [30]

The key concept of psychohistory was an extrapolation on history, sociology and mathematical statistics, and according to Asimov the constructed science functioned as a fictional tool that enabled him to write future history. The science itself provided a conceptual framework for the plot that would continue over more than twenty individual works, and became an important narrative theme for the readers.[31] Technology as such is of less relevance, and the projection into far future eliminates many contemporary concerns. A re-occurring theme however is individualism, set against the plan of Seldon as an inevitable mechanism controlling the future of society. The invented science of Psychohistory becomes an analogy of SF forecasting in itself, as it takes on a leading role in the drama.

There is also work that relates very directly to architectural speculations, both in relation to architecture as a discipline, and architecture as geometry. In the short story '... And He Built a Crooked House' by Robert Heinlein, architect Quintus Teal regards the efforts of his Californian peers of the time as "faint-hearted, fumbling, and timid," and suggests that a house should take on far more dynamic qualities [Projects II: p.167]. Inspired by mathematics, he turns towards multi-dimensional geometry and employs the tesseract, or the hypercube, as a metaphorical model for his design of a new dwelling for the family of his friend.

"Think of the infinite richness of articulation and relationship in four dimensions. What a house, what a house —" [32]

The narrative explores the navigation of a spatial construct of this type, including the psychological distress the characters face as they need to construct speculative models in order to comprehend the spatial complexities of four-dimensional space; that "in a four-dimensional figure a three-dimensional man has two choices every time he crosses a line of juncture, like a wall or a threshold"; crossing such a line in an aware state would make the person end up in the expected space. If unaware he or she would leave the tesseract and enter "normal space," leaving the house. Additional sublime experiences occurs at the "edges" of the space; the narrative solution to how the four dimensional structure intersects with the three-dimensional space of our world is a number of different intersection points in different locations and orientations; a window facing down from a point somewhere above the Empire State Building in New York, a seascape view with the ocean above and the sky below, or an alien seeming landscape that ends up being the Joshua Tree National Forest.

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24 Robinson, Kim Stanley, *Green Mars*, Bantam, 1993, p. 13

25 Jameson, Fredric, *Archaeologies of the Future: the Desire Called Utopia and other Science Fictions*, Verso 2005, p.396.

26 ibid., p.410.

27 Banks, Iain M., Excession, *Orbit*, 1996, p.272

28 Banks, Iain M., *A Few Notes on the Culture*, http://www.futurehi.net/phlebas/text/cultnote.html (9/1 2010)

29 Jacobs, Alan, 'The Ambiguous Utopia of Iain M. Banks,' *The New Atlantis*, Summer 2009 http://www.thenewatlantis.com/publications/the-ambiguous-utopia-of-iain-m-banks (9/1 2010)

30 Asimov, Isaac, *Foundation*, Gnome press, 1951

31 Asimov's concept of Psychohistory has no relation to the Psychohistory studies within psychology, and was formed as a plausible progression of science based on intuitions rather than scientific extrapolation. *Asimov Vault, Sound Recordings*, Interview conducted by Terry Gross in 1987 http://homepage.mac.com/pockyrevolution/asimov/multimedia.htm (12/8 2011)

32 Heinlein, Robert A., '...And He Built a Crooked House,' first published in: *Astounding Science Fiction*, February 1941. Reprinted in Heinlein, Robert A., *The Fantasies of Robert A. Heinlein*, Tor Books, 1999

Heinlein's short story can be seen as speculation on the experiential effects of multi-dimensional geometries, through a metaphorical narrative, but it is also challenging assumptions of how we perceive spatial complexity in general. While still firmly based on orthogonal geometry, it transcends recent more fluid spatial configurations completely by adding another spatial dimension. This fundamental speculation is still valid as reference in the appreciation of how geometrically and organizationally complex architectures may be experienced in a literal sense rather than how complex geometry is applied as a formal principle.

Architecture may also operate as an actor, or a villain in a quite literal way. In 'The House of Leaves' by Mark Z. Danielewski, the new residency of the Navidson family is the subject of both a spatial mystery, and a multi-layered research venture [Projects II: p.167]. Will Navidson decides to document life in their new Virginia house through surveillance cameras in tactical spots. The family soon makes astonishing discoveries; the dimensions of their new house are flawed, it is larger on the inside than the outside.

"It would be fantastic if based on footage from The Navidson Record someone would be able to reconstruct a bauplan for the house. Of course this is an impossibility, not only due to the wall-shifts but also the film's constant destruction of continuity, frequent jump cuts prohibiting any sort of accurate map making." [33]

The novel has a spatial complexity not only as the subject of its narrative, but also in its structure. The book consists of at least three annotated narrative layers. The Navidson family is lost in their house, but their films and notes are found by Zampano, who carefully makes a written and annotated record of their content. Zampano dies and his record is discovered by the new tenant Johnny Truant, who adds an additional layer. The printed version of House of Leaves is vast, complex and multi faceted enough for multiple readings and game like experiences. The fictive narrative of its conception also suggests a remediation process [Contexts I: p.31]; from the spatial transformation of the house, to film, and to three written layers of very different quality and style (including typography), results in a cross referenced multi-media work that is as much structure as content. [34] Beyond the complex reading experience, and relation to remediation, the book has been seen as an example of hypertext literature, albeit in printed form, as well as its innovative use of color. [35] The spatial affects experienced by the multiple authors in the book, and potentially also by its readers, have in the book are also compared to the notion of the uncanny – unheimlich. [36]

The underlying theme of spatial anomalies provides a mystery enhanced by the mode of writing, which can be seen as a remediation between different media and different styles of writing, but also an extrapolation of academic writing in which fictional multiple characters allow a nested narrative. The mix of annotations and references of fictional as well as real origin amplifies this, and relates the House of Leaves to disciplines such as architecture (identifying the characteristics of the house throughstating that it is nothing like a vast number of contemporary architectural references), psychology and literature (by references to the house by fictional experts).

Architecture may make up a framework, that becomes active only as social and political agendas intertwine. An extreme political system, extrapolating a contemporary social tendency to disregard what does not directly concern us, sets the framework for 'The City & the City,' where China Mieville presents the two cities of Beszel and Ul Qoma, co-existing in the same physical space, but with two completely isolated populations [Projects II: p.168]

"When I was fourteen I saw Breach for the first time.
The cause was the most common of all such – a traffic accident." [37]

The speculative factors are in the novel driven by the Law of Breach, there are no other physical constraints or other physical boundaries that prevent the characters from interaction over the city boundaries. Mieville explores how this artificial construct may become as real as any physical border, through the acts of un-seeing, un-sensing and un-thinking, and through the direct punishment for any breach of these conventions. This active denial of the events in the immediate physical environment is omnipresent in the story, and turns into a critical discussion on how culture may be purely relational, constructed through social conventions and language. Ultimately it can be seen as interplay between co-existing laws; the laws of Beszel and Ul Qoma, and the Law of Breach, and how the denizens of the cities are always reflecting on this. [38]

Modes of Speculation

As exemplified in the previous references, extrapolations on technology and other aspects of society today may very well have effect on spatial, social, cultural, political and environmental issues. The concepts of world-building and forecasting are essential in the establishment of alternate realities that can produce cognitive estrangement, but are not necessarily set in the future (Danielewski), nor do they require actual physical changes to the world produced (Mieville). Extrapolations can also operate in reverse, based on requirements of an alternate way of life (Banks). The intended purpose of SF literature also goes beyond the initial novum coupled with cognitive effect; it can explore the characteristics of theoretical spatial dimensions (Heinlein), it can suggest new sciences (Asimov) and use likely future events to discuss relations between environment and society (Robinson). The purpose of individual works of SF also differs widely; it could present improbable situations in order to widen senses (Heinlein), it can imply that systems we take for granted are actually constructs (Mieville), it can extend modes of writing into other domains (Danielewsky), it can discuss issues of individuality and society (Banks and Asimov) or it can provide insight in how humanity interacts with the environment (Robinson). Employing cognitive estrangement, it extends the boundaries of the plausible, to allow a range of issues to be explored.

Written SF naturally operates through the medium of writing, but the additional constructs necessary for the creation and explorations of new worlds can perhaps be regarded as media

on their own terms. Extrapolations may result in proposals for alternate scientific fields, in which the narrative demands partial construction of inner logics, or evolves successively through the writing. Visions of estranged physical environments may re quire the use of geometry in order to redefine the logics of space. Proposals for alternate societal systems require an understanding of the logics of society as well, in its different formations (or functional systems). The science fiction writer devises, or designs, the worlds he or she requires for the unfolding of plots and narratives, with a base in current knowledge and must be able to see potential alternate realities were others do not.

The notion of utopia (or dystopia) is frequently associated with the field of SF, especially in the sense of how world-building, and the narrative mode of writing can further contribute to utopian thinking. The reader of SF typically indulges in the genre, which to some degree diffuses individual work, but also makes utopian thinking to certain extent a part of his or her mindset. It has been suggested that the SF devotee may employ creative methodology learned through SF when solving problems, tends to see visions of the future that may be influenced by actions in the present, and is able to extrapolate trends or dismiss predictions by others.[39] If this is true, such a mindset would certainly be useful for any architect hoping to influence the future by projective practice. With or without explicit admitted associations, such abilities can be identified in the experimental practices discussed in the previous section. In extension, the different modes identified in SF writing can also be associated to these practices. Extrapolation of technology is perhaps the most legible feature, which in several cases can be seen as crucial for formal design and conceptual development. In Archigram, this lies close to technology transfer, in the sense that the technologies proposed often already existed in other fields. Constant used similar references, but based his initial work on the concepts formed within the SI movement, which added a critical layer to his work. Superstudio can on the other hand be more closely related to SF as a literary medium, through the specific projects that employ a speculative narrative (again the 'Twelve Cautionary Tales for Christmas), and the direct relation between architecture and human life can be related to the notion of cognitive estrangement through narrative means (as in the Five Fundamental Acts project). These practices also operated in popular culture through fictional modes, and employed different media to communicate architectural novums, but the objective was clearly to provoke and discuss the potential of architecture specifically.

The aesthetics of SF beyond the concepts discussed frequently also introduced terminologies that support the characteristics of the worlds introduced, which could be compared to the terms that have emerged within the digital design field. In the previous SF references, such terms as 'Minds', 'Outside Context Problem', 'Psychohistory', 'Aeroformation', 'Actional structures' and 'Unseeing' are vital in order to convey the notion of cognitive estrangement. In architectural design discourse in general, such terms are used to form an (often internal) discourse, and becomes legible only to those who are familiar with them. They are not necessarily deployed as terms that amplify the experiences of proposed architecture, but rather as ways to discuss such experiences at an advanced level (compare with the notion of 'affect'). What they do share is the allusive quality of resemblance; the terms could be interpreted and carry the potential for intuitive understanding, or misinterpretation, as in the use of the idea of performance.

Summary

- Science fiction studies includes a number of concepts that directly relate to projective thinking, based on the employment of extrapolation on the present into the future in order to propose alternate situations that combine the familiar with the unknown, inducing an experience of cognitive estrangement.

- The speculative environments of science fiction are explored through the narrative, but also depend on that the constructed worlds are engaging to the reader. It is however the social, cultural and political implications of extrapolations that makes the exploration possible; without these elements of fiction the proposed new conditions would remain a simplistic idea.

- The relation between science fiction and speculative approaches within digital design can be regarded through several approaches. A basic level may involve being immersed in the speculative environments of SF in order to free the mind of preconceptions. Terms such as extrapolation are partly already at work within the field, in the way design techniques and technologies from other fields are transformed into an architectural context; while terms such as technology transfer could be applied here, such transfer requires careful reconsiderations at the level of SF extrapolation in order to make these technologies viable. An operational level involves the speculation itself; present focus on formal innovation, fabrication and to some degree process development is supported by conceptual discourses, but does not usually include the extended speculation on the transformative qualities of such architectures in regards to effects on culture, social issues, politics and life in general. As discussed previously, such involvement certainly exists within architectural discourses, but has not been further developed within the field of digital design.

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33 Danielewski, Mark Z., *House of Leaves*, Pantheon Books, 2000 (2-color version), p. 109

34 Hayles, N. Katherine, 'Saving the Subject: Remediation in House of Leaves,' in *American Literature* 74.4 (December 2002), p. 779-806

35 Brick, Martin, 'Blueprint(s): Rubric for a Deconstructed Age in House of Leaves,' *Philament online journal of the arts and culture*. http://sydney.edu.au/arts/publications/philament/issue2_Critique_Brick.htm (13/8 2011)

36 Bemong, Nele, 'Exploration # 6: The Uncanny in Mark Z. Danielewski's "House of Leaves",' in *Image & Narrative Online Magazine for the Visual Narrative*, 2003 http://www.imageandnarrative.be/inarchive/uncanny/nelebemong.htm (13/8 2011)

37 Mieville, China, *The City & the City*, Del Rey Books, 2009, p. 65

38 Daniel Hourigan has suggested that the way that the main character relates to the multiple laws can be compared to the Lacanian concept of juissance – taking pleasure in the suffering from a symbolic limit. Hourigan, Daniel, 'Breach! The Law's Jouissance in Miéville's The City & The City,' in *Law, Culture and the Humanities* May 25, 2011

39 Hartwell, David, 'The Golden Age of Science Fiction is Twelve,' in Gunn, James & Candelaria, Matthew (ed.), *Speculations on Speculations: Theories of Science Fiction*, Scarecrow press Inc., 2005, p. 281

Spatial Speculations

If science fiction is not necessarily predictions of the future, but rather reflections on the present, or a preparation for changes in society that are inevitably going to happen, there seems to be a relevance for architecture, a discipline that is actively engaged in the change of society. Could the concepts discussed previously be adapted into a mode of design thinking that allows more informed proposals for future scenarios, and prepares architects for changes in our mode of operation as much as it can facilitate relevant projections into the future?

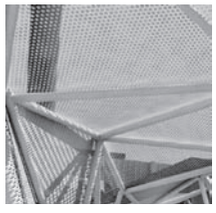
Is there a need to expand the current scope within the digital design field, as to include a speculative layer for a wider exploration of the experiments conducted, or can a speculative approach be included in already existing modes of design? Can this be a way of incorporating valuable concepts from fields like SF into the discourse, and a way to explore the potential of new technology and its potential for the social and cultural performance of architecture? Can the ideologies that may already be present in digitally driven design of architecture today be reinterpreted through these means? The efforts to link simulation software o design software may be analogue to the test of the concept that the SF narrative performs, but it usually only concerns the quantitative aspects of the design. A narrative explores on many qualitative levels, including experiential effect as well as cultural, social and political consequences. On the other hand SF as fiction investigates ideas, and coherency of the framework of a text is based on cognitive recognition of its viability, as well as the immersive aspect of its narrative, while the framework of architectural design, even in a speculative mode, is often invested in research on how to make designs come real. In digital practice and parametric design, computational logic has allowed us to not only suggest things that seem possible; through relational models and analytical software we can to large extents develop designs that could be realizable. In a sense, we have accomplished to build the experimental world, but we have a hard time exploring its performance beyond technical or experiential characteristics. While the directly visual relation between architecture and science fiction most apparent in film is avoided here, there are still aesthetical concerns in the application of SF within architecture. This requires a deeper understanding of a speculative approach in regards to the current aesthetic discourse of architecture in general and in digital design in particular.

Design Projects Enquiries

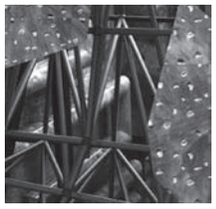
As discussed in the brief overview of historical experimental practices, different notions related to SF can be seen within architectural design, and projects may operate on a speculative basis with different objectives. There may however also be relevant to discuss the concepts introduced from SF Studies in the context of project development. This could entail setting the scope and agenda of the project, affecting important design decisions and ultimately bringing speculative qualities to the design proposal. It may be based on extrapolations on current conditions of particular sites, of changes in society or the future of material science. The speculative outcome could be demonstrators of future material applications, potential new workflows or new architectural applications. In these perspectives, it could be argued that the speculation remains within the project confinements, and is employed in a way that benefits project development, although the knowledge gained may inform future project processes. In rare cases, the speculative approach may provide a project which in itself could induce a notion of cognitive estrangement in a wider context; in analogy to the work of Archi-gram, Superstudio and Constant.

When the architectural design studio in education is regarded as a venue of experimentation, this also entails that the design projects must provide a context for such experiments. The student project is not subject to all aspects of practice, and so, friction must be introduced with a speculation also context, collaborative processes and construction issues. Projects may of course be deployed in situations that can be well researched, but any innovation in complex design (that in practice would require collaboration), advanced production or alternate use, would required an extrapolation of the means, resources and situations addressed. This in turn creates an environment in which speculation is enabled, and encouraged, as a mode of design, combining design based on what is known, with design that assumes and therefore liberates the student from restrictions given in practice.

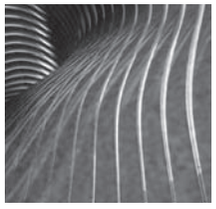
In a context when new design methods are implemented in professional practice, a speculative approach may be necessary in regards to alternate design processes and collaborative models, in which extrapolations on current practice could provide a basis for alternate models of working. This is in most cases an iterative process, and may require initial parallel development, i.e. employing certain areas of a project to explore the potential of alternate design processes without asserting the project to the risks of failure. This situation can be identified in certain of the Dsearch projects, presented in the thesis. The direct engagement in project workflows cannot be disregarded, and over time key findings in design approaches need to be implemented.



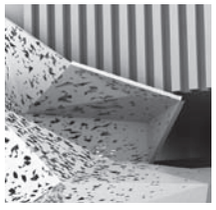
A speculative approach in scope setting of projects may be introduced early, and be based on different criteria. The historic development of the site could be investigated, in order to inform future projections. In the '**Share / Mix / Invite**' project, this entailed an understanding of past development of a power plant, where new areas were added as needed, in a way not to limit the operations of the facility and allow future expansion [Projects II: p.120]. With the objective of adding structure that did not directly take part in daily operations (i.e. a visitors' center), this study entailed finding locations for minimal impact on operations, yet enable the public access to key locations.



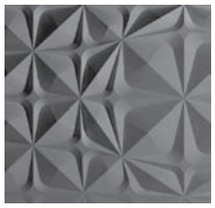
Early speculative investigations may also be directed towards future use and programmatic conditions, such as the starting point of the '**Amongst the Machines**' project [Projects II: p.132]. Here, the student suggested that there is a potential mutual benefit between a proposed new power plant, and public use in the form of a sports facility. A primary argument was that the acceptance for industrial expansion within a sensitive urban area may be enhanced with the introduction of public programs. A different argument was made from an architectural standpoint; based on an intuitive understanding that industrial areas offer certain an aesthetic attraction to certain individuals. The selection of a climbers' center was made with this in mind, as well as the spatial and structural potentials in combining a power plant with vertical climbing walls.



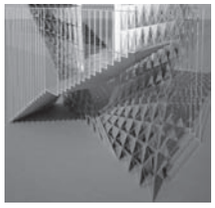
Initial spatial assumptions may also be regarded as speculations, in particular when they set an agenda to be fulfilled by the development of parametric systems. In the '**Labyrinth Wall Pavilion**' project, the selection of two spatial references; the forest canopy and the cave, was later abstracted and used as a target for spatial design and parametric system performance. A related approach could be seen in the '**Slumbering Space**' project, with the initial starting point in very physical aspects of the body, abstracted and transformed through design interactions into a flowing spatial condition. There may be a question if the sleeping and awake states were relevant beyond the origin of this formal approach, but the design outcome suggests that certain traits are still present. In this project there are also speculations of future potential design methods that were only explored in parts; the suggested integrated model could be seen as a speculation into future design processes, or a roadmap for continued project specific method development. [Projects II: p.108, p.114]



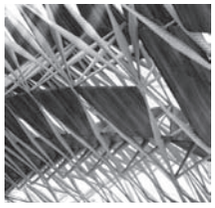
There are as discussed previously relations between new design methodologies and architectural outcome. The '**Adjust[ed] Folding**' project further explored potential compound models, introducing daylight evaluation as a design criteria, but in addition the formal priniple of triangulation suggested speculative approaches to spatial design and performance. This influenced both the organization of the proposed visitors 'center, and potentially the architectural performance in terms of spatial experience, in particular in regards to the continuously shifting floor planes. [Projects II: p.126]



The speculative focus on new potential processes is of importance within implementation in practice, when project development depends on several participants with different skill levels, and different designing roles. The '**Koggen Ornament**' project was started very late in the design process, and a formal principle needed to be established in very short time. The variations made possible through the parametric development could however be manipulated by non-specialists, and in this sense it introduced a new potential collaborative model. [Projects II: p.146]



A similar principle was employed in the '**Reframe**' project, in which direct modeling could be used to control the parametric system. This project was also based on a different speculative approach, one of parallel development, as it took opportunities given in a competition entry to explore a formal system that could be integrated in further refinement of the proposal, but also be applied elsewhere. The '**Quality Globe Hotel**' project operated on a similar principle, and again direct modeling manipulation of overall form, as well as control lines, would shift the outcome of the parametric system. In this case initial formal principles were evolved into a digital design trope yet to achieve its final configuration, based on late stage understanding of programmatic distribution in the overall project. [Projects II: p.152]



More comprehensive projects allow series of speculations, from early stage approaches to process steps emerging during the development. The initial interest in the '**Flexible Space Frame**' project in the performative capacity of a certain type of composite configuration; there was no starting hypothesis beyond looking for the potential of developed prototypes [Projects II: p.96]. Each iteration could be seen as a proof-of-concept, and the project commenced through a process close to material science. Each design step introduces a new level of speculation, which is continuously informed through digital and physical prototyping.

The initial understanding of the flexible performance of a small model was the base of an assumed system performance, a hypothesis that could be evaluated through additional design development. The investigations of fabrication principles that retained the expected performance, developed by means local to the school, depends on the extrapolation of such fabrication technologies to large scale production. The shift from a production technlogy that could be simulated by simple means, to an advanced use of carbon fiber filament winding depends – while being informed by research into references – on speculations and extrapolations of technology transfer into the building industry and the possibility to employ mass production of previously customized parts. All such informed speculations of processes and technologies lie at the basis of the overall proposal, which in itself includes speculation on performance of the system, and the

resulting environment, as well as expected behaviors in the public. While the project suggests alternate use, it is highly involved with the iterative and procedural development process rather than well informed and evaluated speculations of its final form. The primary site is well understood, and certain issues that are seen as problematic have been identified. In the end it is however obvious that the modes of testing the final design outcome through models and renderings are much more speculative depending on extrapolations of site conditions, public behavior and experiential effect when compared to the design iterations. These however, may be regarded as series of re-informed extrapolations, instrumentally supported by digital design tools and material tests, in effect extrapolation in the form of iterative prototyping.

The **Subversive Resilience** project explored the potential architectural use of photo bioreactors for algal cultivation [Projects II: p.138]. The project was based on an extrapolation of contemporary algae farming technologies, informed by research and advice from experts in the field, in the formation of an initial thesis.[40] This allowed the student to make the initial decision that the scope of the project; to develop an urban public algae farm, was viable in terms of economy and program. The hypothesis for the speculation of the project could then be reassessed; the "research question" (in terms of design) was framed as follows: how could such a facility be design in order to be viable in an urban semi-sensitive area, and how could the technology itself be converted into an architectural system in the sense of experiential effect as well as pedagogical content (to inform the public of the processes of algae production)?

As an active extrapolation, the student then made use of the design tools introduced in the design studio. She explored formal variations in the modeling software. She investigated structural performance in the structural evaluation software. She developed a systematic understanding of all technical and architectural systems and their associations in a diagrammatic mode, which also integrated issues such as environmental control, public interaction, and prototypical spatial configurations. This diagram was developed in an iterative way, and was an important framework in the later stages of the project.

Post design phase she reinterpreted her work in a narrative that initially emphasized the experiential effects in the project, followed by a strong argument through technical performance.

"Imagine you are in a building unlike almost anything you've seen before. You move amongst an intricate patterning of tubes, overlaid in different colors that create a 3d-dimensional moiré effect, and different lighting conditions; tubes that also divide spaces and form them to lead you through the building. They hang down into the room, and where they divide and open up you are led from one room to another, through spaces that form continuity, yet have separate qualities, which often seem to depend on the formation of the tubes. As you move forward, you notice places that are within visual range but that you cannot reach ... ... There's a hidden agenda in this. An environmental programme that goes beyond trying to use as little energy as possible and to minimize footprint. What architects in general cannot do, is influence what / type / of energy we're dealing with. This building works with energy supply as a programmatic premise." [41]

All aspects were vital parts in the exploration of potentials; the initial research that set the boundaries in terms of the algae farming technology, the formal / structural iterative investigations of formal massing, the refinement of spatial organization through models, plans and sections, the physical models (that actually included circulating fluid), the system diagram and the final narration to communicate the project not only as a formal design, but also as a process of investigation.

The enquiry into the design projects featured in the thesis already suggest alternate approaches to speculative modes of design in architecture, from generic principles applicable in many cases, such as the employment of site or program, to approaches more inherent within a prototypical design approach employing digital design methodologies. In these cases, the narrative aspects of speculation, as present in SF, have been transformed to the narrative of the design process. With the exception of the 'Subversive Resilience' project, there have been no textual examples of a speculative mind set, which does not entail that the project outcome could not be employed in such manner. It could however be interesting to further discuss the nature of narratives, in written form, in relation to digital design.

Architecture Fiction

SF writer Bruce Sterling has suggested 'Architecture Fiction' to be a new mode of speculative writing for architecture, directly influenced by a J.G. Ballard text triggered by a visit to Utah Beach, and the experience of the remains of Hitler's Atlantic wall. Sterling based his notion on the following quote from Ballard's text:

"All of us have our dreams to reassure us. Architecture is a stage set where we need to be at ease in order to perform. Fearing ourselves, we need our illusions to protect us, even if the protection takes the form of finials and cartouches, corinthian columns and acanthus leaves. Modernism lacked mystery and emotion, was a little too frank about the limits of human nature and never prepared us for our eventual end." [42]

The theme of Architecture Fiction later became a recurring topic on Beyond the Beyond, Sterling's personal blog on the Wired magazine website, as a constant sampling of innovations within architecture that he conveys to the readers of the magazine.[43] Stirling has also written a short story inspired by Greg Lynn's work (and writing) titled 'The Growthing'.

"Milton's daughter sobbed aloud as she clutched the chaise lounge." "But why can't I take the chair? I grew it myself from a bean!" "Gretel, there is no room for that thing on your flight. Besides, a chaise lounge isn't really a 'chair'"

Gretel flung herself in anguish on the biomorphic furnishing. In her frenzied teenage grip, the chaise gave a deep pneumatic moan and sentimentally changed color.
"But I love my big bubbly sofa! And Mom's got the stupidest dead furniture in Jersey! My bed at home's made of wood, Dad! I'm your only daughter! How can you make me sleep on wood?" [44]

This text is his only explicit writing on this theme, and actually has stronger relation to material science speculation and design than architecture, but his notion of architecture writing has given rise to discussions on a 'new' literal mode of speculative architecture.

A parallel can be drawn to other fields of design. Julian Bleeker, designer and researcher at Nokia Design, has proposed 'Design Fiction' as a way to bring science fact and science fiction together and to tell speculative stories unhindered by future predictions, interpretations of focus group rationales and market demands. Regarding science fiction as speculations about future worlds, he believes there is a direct link to design.

"Design is more than specifications. A conclusion to this point might be to consider elevating science fiction, to that of a deliberate resource, a mechanism or approach as one might employ any design resource, and do so in order to consider the culture questions that are not always done particularly well with the technical instruments and techniques used to construct technologies. Rather than something separate from the conventional methodologies of technological design, employ science fiction in order to engage in a design practice that can examine and discuss the properties, consequences and ideological stakes of emerging ideas at the point in which they begin to take on material form?" [45]

Bleeker, an interaction designer, uses examples of interface design that has a strong tie to visions of near future technology featured in SF movies.[46] The contemporary situation, in which technology has enabled ubiquitous computing to become mainstream, may make the step between fact and fiction smaller in the field of interface design, but his arguments that fact and fiction frequently swap properties, and that this enables material practice to be engaged in the an analysis of the future, can be extended to a wider field. According to Bleeker, fiction allows the creation of objects that help thinking through matters-of-concern, and employing a science fiction approach could allow the designer to speculate on future use and cultural impact of new products and services.

Greg Lynn references SF as "a medium for expression, since it is a more narrative way of describing the desired atmosphere and spatial quality." [47] He suggests that science fiction is "speculative without being promissory: new directions, technologies, lifestyles, visions, forms, materials, atmospheres, intelligence, and sensibilities are presented as already fully realized in the cultural sense." He suggests that this mode of writing is less distanced from contemporary design discourse than conventional architectural theory, which according to Lynn has either become detached from the digital design field and turned to history, or has become a "marketing copy for yet-to-be-developed software tools." [48] As he was working on his Embryological House research project, he recalled the J.G. Ballard short story 'The Thousand Dreams of Stellavista' [49], in which 'psychotropic houses' adjust themselves to their inhabitants and through time would be affected by the moods of previous owners. In turn, this inspired him to write a short story of his own, including a speculation on how the Embryological House could be conceived as a home which would turn truly organic, where materials bond and evolve continuously, and where "organic vitality is harnessed and the natural processes of auto-cannibalization catalyze a new parasitic sensibility fed by readily available genetic technologies."

"His newest and most extravagant clothing purchase could only be worn from dusk until dawn without suffereing the same fate as its amphibious genetic parents: sensitive iridescent skin damaged by increasing ultraviolet rays. Even more damaging to these fragile reptilian skins than sunlight is the repetitive mechanical impact of cathode-ray displays. After four hours in front of the television, milky stripes were already visible below the slick surface of his slacks, a rote mechanical record of the simple temporal rhythm of scanning technology. Contrasting the gridded space of the screen scans was the biologically engineered rhythm of growth distributed fluidly across the slacks adapting to the tailoring and seaming of the garment. Like any grown thing, its structure, seams, and panelization were intricately fused into a synthetic pattern of discrete striated articulation and smooth continuity across members." [50]

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40 Fredrika Gullfot, PhD in Biotechnology and CEO of Simris Alg, the second industrial algae farming facility in Sweden founded in 2011, gave valuable initial advice and followed the project development. The completed thesis project was also presented by Anna Teglund at the 'Alger och innovation: enzyme för regional utveckling?' Symposium at the Simrishamn Marine Center in June 2011, as part of a venue discussing the value of biotechnologies for regional development.
41 Teglund, Anna, verbal presentation at final review, June 2011, excerpt
42 http://blogs.walkerart.org/offcenter/2006/03/20/science-fiction-and-architecture-fiction (14/8 2011)
43 http://www.wired.com/beyond_the_beyond/2011/08/architecture-fiction-wikihouse (14/8 2011)
44 Sterling, Bruce, 'Growthing,' in *Greg Lynn Form*, Rizzoli International Publications, 2008, p.283, excerpt
45 Bleeker, Julian, 'Design Fiction: A Short Essay on Design, Science, Fact and Fiction,' *Near Future Laboratory*, March, 2009, p. 78 http://nearfuturelaboratory.com/2009/03/17/design-fiction-a-short-essay-on-design-science-fact-and-fiction/ (16/9 2011)
46 Bleeker's most well known references in this regard include the holographic image systems on Blade Runner, the listening posts of the Dark Knight and the gesture interfaces of Minority Report.
47 Greg Lynn recites from his own work, *ArchiNed News*, (7/3 2002) http://www.classic.archined.nl/news/0203/greglynn_en.htm (9/1 2010)
48 Lynn, Greg, *Greg Lynn Form*, Rizzoli International Publications, 2008, p.281
49 Ballard, J.G, 'The Thousand Dreams of Stellavista,' in *Vermilion Sands*, Jonathan Cape, 1971
50 Lynn, Greg, 'A New Style of Life,' in *Greg Lynn Form*, Rizzoli International Publications, 2008, p 299, excerpt

The reference to Ballard's particular short story and the theme in Lynn's own novel is not a coincidence. While he is perhaps today most known for his innovative use of fabrication tools to intro. duce aesthetic surface qualities to his projects in scales from kitchen utensils to buildings, or his interest in the discourse on aesthetics, the early years of his practice with digital tools involved an interest in generative processes; he employed animation software that to certain extents induced a loss of control. The generative approach behind projects such as the Port Authority Competition and Citron House provided the opportunity to develop them in terms of behaviors rather than static form. More recent work entails a much more controlled design approach, in which formal principles guide the development, but the employment of science fiction narratives bringing the idea of the uncontrolled back through the actual kinetic and material performance of his visionary project. Rather than involving generative mechanisms as a design tool, the use of the science fiction story allows a suggestion on how similar features could play out in reality, through advancement in material composition through biological processes. It parallels the objective of the earlier design project, and allows a deeper investigation.

Adopting particular modes of extrapolation can also move architecture closer to the traditional venues of SF. In the introduction to the exhibition catalogue for the collective exhibition Other Space Odysseys, editor Giovanna Borasi suggests that the recent renewed interest for space exploration and the real possibility for space tourism suggests a reconsideration for similar themes in architectural thought.[51] She argues that the consideration of architecture in environments in the new frontiers such exploration would provide, may also influence the idea of architecture on our planet. Greg Lynn, contributing with two projects in the exhibition, indicates that his interest in science fiction was always in near future events, and that he to him, the NASA space program represented a manifest destiny. In his project N.O.A.H. (New Outer Atmospheric Habitat) he designed four artificial planets for the science fiction movie Divide, with the absence of gravity as an important criterion.[52] Lynn's notion of gravity goes beyond the basic condition that gravity is vertical; instead it deals with vectors, orbits, velocity and slingshot curves around the moon. The second project, New City, was a commission for the MOMA exhibition Design and the Elastic mind, and involved the design of a virtual world; a virtual representation of the complete online community with a focus on the experiential effects that could be provided through architecture. Again with gravity an open field, to be constructed at will, the design was based on a series of manifolds that would be reconfigurable and distorted, rather than using a plane or a sphere.[53] The programmatic influence to the design came primarily from alternate mapping of networks and telecommunication systems, in the form of seven continents that would constantly move through each other and intersect. The experiential effect is further refined by the introduction of a number of lenses, which would provide different ways to access information, visualized in a way not constrained by an urban space. The final exhibition at MOMA included faceted screens with back projections, providing an immersive effect of the New City, suggested by Lynn to be a trailer for the project, rather than an experience near the proposed in the visionary project.[54]

Kazys Varnelis, the Director of the Network Architecture Lab at Columbia University, pursued the idea of architectural fiction and suggested that it "identifies a new kind of interaction between architecture and the arts in which architects transgress into the territory of the novelist to themselves envision alternate realities and shape narratives."[55] He suggests that the collapse of the dot.com boom made creative capitalists turn back to the heaviest form of capital – building, and a global building boom in and an epitome of economic fiction, when in fact growth is minimal. In this context he suggests that rethinking architecture is crucial, and that architects may need to broaden their territory beyond building. Architecture fiction may also allow architects to "pause and pull back from the thoughtless building that consumed the field during the last boom." He refers back to Giovanni Battista Piranesi, who according to Varnelis represents a similar approach in the 18th century. He quotes film maker Werner Herzog as a final argument: *"... what moves me has never been reality, but a question that lies behind it: the question of truth. Sometimes facts so exceed our expectations – have such an unusual, bizarre power – that they seem unbelievable. But in the fine arts, in music, literature, and cinema, it is possible to reach a deeper stratum of truth – a poetic, ecstatic truth, which is mysterious and can only be grasped with effort; one attains it through vision, style, and craft."*

While a practice of architecture fiction still is at an early stage, it seems to relate to speculative writing that includes architectural elements, and investigates issues of architectural concern. It may also suggest a design mode which is fictional (in his initial statement Sterling also relates to Archigram), in the sense of being speculative. Such design modes could, in analogy with science fiction, be near future or highly speculative, but they would need to suggest if not a narrative at least a scenario. A possible situation for such projects to evolve is the design studio within architectural education [Projects II: p.94].

Speculation in the Digital Design Field

The formal explorations in digital practice has introduced a novum, a newness, in the field of architecture, through the estrangement induced by performative effects, with well defined processes documented within parametric systems that both control the design and proves its plausibility. The iterative fabrication of prototypes has the dual purpose of suggesting a new performance of architecture (in a multiple sense) and testing how a proposal could be produced in full scale. The technology transfers from other fields can be seen as extrapolations, and speculations, in the SF meaning, are made on how projects could be realized and what their formal performance and effect may entail. Digital fabrication can in this sense be seen as well defined experiments in which particular production technologies are tested in partial isolation. The aesthetic effect may however overwhelm a "reader" external to this field, and a further refinement of the cognitive aspects may be required. Perhaps current experimental practice can be seen as performing transformations; in the sense that the employed technologies lie far beyond what the current building discipline can accomplish. In order to advance the field of digital design there may be a need to conduct forecasting; by looking

more carefully at the recent trajectories of the experimental field as well as the current status of the building industry, scenarios that also suggest the potential implications on a societal, cultural and individual level can be developed.

In science fiction there is no need to argue for the relevancy of what is proposed, the reader is rather experiencing a double sensation of amazement and understanding, and can often relate the speculation to contemporary issues in society, through the effect of cognitive estrangement. Science fiction requires the use of meta-levels in the writing of novels; there is a need to establish a world (even if it may not differ too much from our own), and there is the parallel activity of creating the characters, narratives and plots as in most literature. Even if the conception of such artificial worlds follows a more intuitive principle, the world still becomes a system and a framework that must be explored in an unfamiliar way; the writer must understand the rules of his or her own creation, and develop a plausible mode of operation for all (fictional) participants. While science fiction following the concepts presented here, is seen as a genre in which artificial worlds are created according to certain principles linked to our reality; the idea of extrapolation, there is a need for a structure to how this extrapolation is facilitated. Some writers are closer to science (some may be scientists), while others use alternate means.

In a similar way, a cognitive estrangement within architecture may suggest the combination of utopian thoughts and pragmatic contextualization. The argument for relevancy by a discourse or reference becomes less significant as this architecture should be convincing by its performance in itself. In order for digital culture within architecture to come of age, there is a need to move beyond the reliance of process or effect as a pure motivation and solitary driver. A prototyping approach may be regarded as an iterative and re-informed mode of extrapolation within the design process, that requires not only continuous re-evaluations of the aspects explored, but also a mode of re-purposing the design exploration. The employment of extrapolation may nonetheless, be most relevant in the initiation of a design project, as means of establishing an initial design concept.

The objective of the speculation within the architectural design process can be multiple, as discussed previously. It could be the formal proposal of an architectural project in which the experiential effect would be different from the ordinary. It could involve alternate processes, and the evaluation of how they perform. This could suggest extrapolations on existing processes of today, or processes that depend on new technologies, new business models or new actors within the discipline. The speculative medium of architecture is not necessarily text; all representational modes are of relevant use. The purpose of the speculation is of relevance; a discursive or provocative project aimed to induce debate may rely on representations that communicate intents and suggest effects. A project meant for construction may use alternate form of representation in order to implement innovation in process, production or end use.

Based on the previous discussions on historical precedence within architecture, SF literature and SF Studies, and the design projects enquiries, a framework for informed speculation within the digital design field will here be proposed. There are three different modes that could be identified from the investigations conducted here. The design projects enquiries primarily suggest a speculative approach within the design process, in which attitudes and principles at different stages can inform a speculative approach that in turn becomes suggestive for the design outcome, or for further development of design methodologies. In relation to the previous overview of the discourses within digital design in architecture, a speculative discourse will be introduced. This should not be regarded as completely divided from existing discourses, but rather as an attempt to fuse a number of currently divided discursive fields. Finally, to extend beyond the digital design field itself, a speculative discipline mode will be suggested, in which the relevance for this approach within a wider community of architects will be discussed. The suggested framework can only be regarded as a first attempt to categorize the potential situations in which a speculative approach could be applied, as exemplified previously, and should primarily be seen as a starting point for further development.

Speculative Process

There are direct implications on modes of practice when SF concepts are appropriated into digital design. While methods such as extrapolation are explained in a discursive or perhaps theoretical way (they do originate from the critique of SF rather from the modes of writing), it may be possible to find other means to relate the two fields together. The notion of informed speculations within in the context of design processes should be related to the modes of extrapolation previously discussed, but the research involved in such endeavors within SF writing, has its counterpart in the prototypical approaches discussed throughout this thesis, as well as in the previous licentiate thesis. As such, they continuously inform design development during the process.

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51 Borasi, Giovanna and Zardini, Mirko, *Other Space Odysseys*, Canadian Centre for Architecture, Lars Müller Publishers, 2010

52 Tittel, Jörg and Ryker, Ethan, *Divide*, 2004 (film not released)

53 'New City' Project developed by Greg Lynn FORM and Imaginary Forces through Lynn, Greg; Frankfurt, Peter and McDowell, Alex, commissioned by the Museum of Modern Art, New York, for the exhibition 'Design and the Elastic Mind,' 2008

54 Lynn, Greg, New City, lecture for Seedmagazine.com http://seedmagazine.com/designseries/greg-lynn.html (14/8 2011)

55 Varnelis, Kazys, 'In Pursuit of Architecture Fiction,' in *Town planning and architecture*, Vilnius: Technika, 2011, Vol. 35, No. 1 , p. 18-20 Available online at: http://www.tpa.vgtu.lt/upload/urban_zur/tpa_vol35_n01_18-20_varnelis.pdf (14/8 2011)

Conceptual frameworks internal to a project, or a practice, are needed to extend the objectives beyond the scope of design technique and fabrication. Technology and new spatial concepts are still valuable components, but here the idea of cognitive estrangement would suggest that current needs in society must be more strongly associated. Speculative innovation must also include an understanding of the potential consequences of such proposals, and preferably be part of the investigation. Unless digitally driven design is only about technology, it will need scope. A further reading of Science Fiction theory unveils a number of qualitative markers that could give additional clues. The consistency of extrapolation, precision of analogy, and width of reference have been suggested important criteria for aesthetics, indicating plausible projections of the future, relevancy to current issues in society and rigor of reference research. They remind us of the need for a legible link between real world issues and experimental work.

The internal organization and processes of a practice is fundamental for an innovative approach, and again technology may very well support this, but is not the answer in itself. As architect come business strategist Paul Nakazawa suggests, a key to intent within a practice lies in the intersections between design practice, internal business development and administrative organizational systems. An adaptive practice needs not only to come up with new design strategies to remain a viable actor, it may also need to restructure itself from within, which ultimately affects the offer given to any market (commercial or not), potentially rebranding both identity and mode of operation.

In relation to the idea of architecture fiction, a speculative narrative could be operating at different levels with different purposes in relation to architectural design. It could be used as an internal reference that establishes common criteria among design participants, comparable to mood boards or metaphors. It could suggest a mode of analysis, in which alternate use or alternate social and political contexts are used in a narrative in order to understand future potential in an existing architectural context. It could employ scenario building in which alternate design proposals are contextualized in order to be evaluated and communicated to external parties. It could introduce a speculative framework that connects disparate design ideas and intentions in order to find a comprehensive and projective prediction of how several previously unrelated design explorations may achieve agency through synthesis.

There is another approach in literature that is involved with instrumental techniques of generating text and narrative. Oulipo employs rules and constraints in the development of new forms and structures, not only for texts but also other media such as painting (Oupeinpo), comics (Ouxpos) and crime fiction (Oulipopo).[56] There are many traits that resemble formalized procedures in digital design. Furthermore, there are traits that can be related to Science Fiction. Jason Henninger suggests that the use of constraints in Oulipo may be related to the scientific starting points in SF. [57] An extension of this idea may entail an Oulipolian mode of SF in which generative means are used to provide structure and framework to writing, and opens up to discussions on the relation between a generative approach in architecturefiction and generative approaches in design.

Certain approaches within the digital design field could already be directly related to ideas of the Oulipo movement, such as algorithmic design and generative processes, but a further development may entail the inclusion of a narrative beyond the steps of the design process, a narrative that may or may not communicate the process behind it, but primarily would perform in an experiential way.

Speculative Discourse

The discourse of digital design is as diverse as the field of Science Fiction Studies. Interestingly, the concepts within SF are more exact in their implications, than the terms presented from the digital design field. This may be due to the fact that the discourse in SF primarily concerns the identification of the genre, while the discourses of digital design often concerns the identity of particular practices, an individual self description to use Schumacher's term, rather than a disciplinary. There are of course more general terms such as fabrication that often are employed in order to communicate innovation and excellence externally from the discipline.

While the relation between architectural design practice and science fiction may be identified in the critical practice, the modes of extrapolation and speculation suggests a stronger tie to the discourse on the projective or performative practices [Contexts 1: pp.39–41]. The discussion in the Reformations chapter very much regards this mode of speculation, but as such it primarily operates within the discipline. An extended model would preferably operate also outside the discipline, and here a narrative approach may prove fruitful. Of particular interest is the notion of affect. Within the architectural discourse, affect has been related to forms that give rise to emotional responses, in particular articulated forms enabled by digital design expertise. It has also been suggested that affect requires that the origins of form remain obscured, not to take precedence over the experience. In SF, cognitive estrangement suggests a quite specific affect; the combination of recognition and alienation, one which may be present in architecture by default (assuming an observer understands that he or she is in fact observing a building, or at least an artifact of known purpose), but this connection between identification and awe in as an experiential effect is not discussed.

Speculative Discipline

A move beyond internal discourse into the wider discipline, and in extents into society, may require a further understanding of the core SF aspects of cognitive estrangement. Here, cognition implies the recognition of relevant issues among the "readers" of a project, which also affects the modes of representation used. The estrangement includes the communication of the potential of new "forms" of architecture, which could entail new aesthetic agendas, but also alternate programmatic combinations and other aspects that relate architecture to society.

As discussed previously, the narrative is not necessarily textual as in written from; the framework and comprehensive view may be achieved through a collection of design projects. This may be compared to the fields of forecasting and prediction, but also to earlier architectural traditions of visionary nature, that also includes an agenda – such as the work of Archigram, Constant or Superstudio. Reference to popular culture can be an advantage, which again can combine different media including narratives as well as imagery that is accessible.[58] At the intersection between digital technologies and speculation lie opportunities not only for short term innovation, but also for long term prediction – in a way that can suggest opportunities not identifiable today. There is however a need for instruments, or at least concepts, for how these predictions may be defined, and perhaps a theoretical framework for how they may be discussed.

As means of empowerment, a practice needs to achieve agency in order to understand the conditions faced, and to interact and affect those conditions. Especially in a time when culture and market is in flux, this interaction needs to be a natural mode of operation. Michael Speaks notion of design intelligence as the capture of intelligence chatter or "little truths" denotes practices able to identify signs of new conditions, and as able to respond to them. The increasing knowledge of production technologies may give new conduits into the industry, but that knowledge is often limited to the use of machines to produce desired results. As the business models of architectural production are changing, an engagement in higher level business processes can provide new solutions for processes and proposals alike.

The interdisciplinary teams of tomorrow may need to be equipped not only with technical specialists and imaginative designers; there may be a role for forecasters or even writers of fictions. Not to sell the project, but to explore the potential effect on society. Not to ensure that the future we're dreaming up is the one we really desire, or to make sure mistakes are not done along the way, but in order to retain an opportunity of utopian thinking that still prevails within Science Fiction literature.

Summary:

- The individual architectural design project can be used to explore speculative processes, or process enablers, in which each iterative step continuously inform and evaluate design decisions (similar to the innovation driven design process discussed in the licentiate thesis), spatial speculations tat also regards site and program, and as investigations for future practice.

- Examples of direct equivalents of science fiction textual narratives do already exist within the digital design field, defined as a mode of speculative writing for architecture, and have been suggested to enable the rethinking of architecture. As such, it may allow an architect to be speculative without obligations, and more related to the digital design discourse than present architectural theory.

- In addition to the different approaches presented in the previous section, three modes of speculation are proposed. A speculative process would operate within the design process, as a speculative framework that connects different ideas and intentions in order to form a comprehensive and projective prediction. A speculative discourse involves the current use of new themes within the digital design field, but would benefit from integrating key concepts from SF studies. A speculative disciplinary mode would entail work that affects the discipline, and support the formation of common goals and challenges.

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56 Oulipo was also discussed in the previous licentiate thesis [Contexts I: p.18].
See also: Mathews, Harry & Brotchie, Alastair, *Oulipo Compendium*, Atlas Press, 2005

57 Henninger, Jason, OuSciFiPo, TOR.COM
http://www.tor.com/blogs/2010/03/ouscifipo (13/8 2011)

58 For a contemporary example see the work of BIG, disseminated in the form of comics.
Bjarke Ingels Group, *YES IS MORE: An Archicomic on Architectural Evolution*, BIG, 2009

Strategic Implementations

> *"In glossing over the deeper truths underpinning our moment of hyper-activity, we fail to grasp the real potential of our own ideas, competences, methods, commitments and priorities. We also fail to grasp our responsibility to work with a better understanding of the consequences of our actions."*

Paul Nakazawa, *course brief*, 2007[1]

While the discourse on digital design in architecture has been focused on the techniques themselves, the aesthetic ambitions associated with them, or the overarching relevance for the discipline, the debate on how daily architectural practice changes with digital design methodology has rarely moved beyond the statement th at it must change. Previous chapters have discussed the specific traits of the digital design field, as based on the inherent design methodology, its discourses, and projects developed through digital design, and the potential needs and opportunities that could be provided with a speculative approach.

To move beyond the isolated project as a venue for innovation in digital design requires preparedness, and an awareness of the potential for long term development. Within the digital design field discourse, ideas on network practice and the use of digital protocols have been presented in various forms[2], but concrete in depth studies on how design practice needs to adapt to use the full potential of digital design environments have been restricted to BIM related production and the exchange of models and information for work flow optimization and quality control. As discussed in previous chapters, digital design methodologies, and prototypical approaches, depend on design methodology in combination with design ambition in order to provide the means and the agency for continuous development. This chapter will discuss the relevance for strategic and management thinking in regards to digital design methodologies, by which the issue of process no longer is dependent only on the procedural qualities of these methodologies, but also regards how to manage digital design as a critical part of an overall architectural design project.

Architectural practice primarily operates through projects. Management issues are therefore often directed towards temporary project organizations, and towards issues such as the coordination of multi-disciplinary teams, construction documentation, procurement, and communication within the framework of the project. From the perspective of the architect, the current role as one of several consultants is often regarded as undermining the potential to bring architectural qualities into projects, and project management is primarily focused on the construction process, not regarding the early stages of conceptual design that are fundamental for innovation through digital design methodology.

Management in design organizations, such as the management of an architectural practice, often involves the following steps; acquisition of client orders, work assignment to teams and overall budget work. The design process itself is guided through important gates (such as concept design or construction documents), but the detailed process within each phase of the process often depend on the particular conditions of the project.[3] Overall project management within the building industry and the overall organizational management lies beyond the scope of this thesis, but the characteristics of digital design field, and the previous suggestions on the need for strategic thinking, suggests that the field of strategic management is a relevant context in which useful terminology can be found for the continued inquiry.

Before commencing, it is relevant to discuss the term strategy, especially within architectural design. The term is in frequent use, and concepts such as 'design strategies' are used with different connotations. It has been used to encompass most aspects of architectural design, as well as a denominator for architectural styles and stylistic principles.[4] It is also frequently used to denominate particular design proposals, especially when displaying comprehensive concepts in regards to form and massing, program, urban relations or structural principles. For the purposes of this thesis, the term strategy is used closer to its original meaning and the subsequent development within the field of management and Organizational Development. In this way, the term digital design strategies entails the strategic requirements necessary for implementing digital design procedures in architectural practice, as well as the strategic relevance for implementing such procedures (rather than the design concept as a strategy for a particular project).

Strategic Thinking and Digital Design

The introduction of digital technology to conventional practice in recent years has already seen the emergence of a number of new specialisms; at first in regards to visualization, later also advanced geometrical modeling groups as well as programmers and analysts. While digital design depends on expertise, it also

depends on the ability to provide agency and purpose to the deployment of new techniques, and a framework to promote innovation employing digital methodology. The development as well as the deployment levels of digital design thereby need to address the architectural implications and issues that are targeted, in order to avoid isolated formal features or pure problem solving that may not support the architectural project at large. Aesthetic discourses within digital design target the architectural qualities achieved. Formalized digital design processes elevate techniques to methodologies, and further the understanding of requirements in regards to skill and management of processes. A strategic perspective that incorporates architectural ambitions with process and skill requirements may be useful for an approach in which digital design methodology, prototypical approaches and formal innovation can be integrated in the overall architectural design process. Strategies are instruments of change; the changes of an environment proposed in a design, the change of a workflow, or the change of an organization. Within management and business organization, strategies have been vital tools for a long time, but the field of strategic management is diversified and there is no single approach. The main purpose of strategic management may be the success of an organization, primarily in economical terms or market shares, but the perspectives and approaches differ. A number of 'schools' of strategic management have emerged since the 1960s, and can be regarded as prescriptive or descriptive, indicating an interest in how strategies should be formulated versus how they actually are formed. The former includes approaches on how strategies are conceived (designed), planned (through a formal process) and positioned (within a market). The latter elaborate on how strategies are formed as part of practice, and refer to issues such as vision and entrepreneurship, cognition, learning, power relations, organizational culture, the environment external to an organization or the configuration and transformation over time.[5]

An architectural practice of course also operates in a market and depends on its ability to make profit. The ambition of this thesis is not to suggest or prove that digital design methodology and prototypical approaches directly provide the means that could improve success in economical terms. The scope is rather to introduce strategic thinking within digital design in order to enable architectural innovation while building on previous knowledge, identifying design as the primary activity within architectural practice. James G. March identifies a relation between the knowledge among individuals in an organization in terms of employing codes, standards and information technology, and the performance of an organization. His findings suggest that fast organizational learning, and adaption to new codes and protocols, may make performance more reliable, but reduce more explorative performance. In management terms, a practice based on previous knowledge and experience can be seen as 'exploiting' that knowledge through refinement and extension of existing competences and technologies, while an experimental practice can be seen as 'explorative,' operating through search, variation, risk and innovation. A practice based primarily on a mode of exploitation may be more successful in short terms, but a mode of exploration may be necessary to adapt to new conditions and be successful in the long run. The preferred relation between the two modes depends on several issues, such as the kind of knowledge involved or the impact of new technologies, and this balance is also affected by the regulatory rules that govern a practice.[6]

The forms of knowledge that are particular to the field of architectural practice are not easily defined in exact terms. Architectural design cannot be confined to the resolution of design problems, even if one would limit design activity to the idea that the architect solitarily defines architectural form. Problems here may better be defined as tasks open to reinterpretation. The overarching task may be to design a specific type of building, which in turn introduces a number of problems, or sub-tasks, that depend on programmatic concerns, contexts, conceptual principles etc. In essence, design problems to be resolved within architectural design are often wicked problems [Contexts I: p.17], and an important part of design work involves problem setting rather than problems solving. Donald Schön identifies problem setting as an important task in many practices, and describes a process of reframing through appreciation, action and reappreciation. The goal here is to understand a situation, and suggest relevant changes, and actions may be taken only to see what follows, defined by Schön as an 'explorative experiment'.[7]

Architectural practice and the generation of knowledge can therefore not be purely goal orientated, but must include the context of the problem, and allow a combination of exploration and exploitation. Björn Linn indentifies two approaches in analogy to exploration and exploitation as important to architectural practice – 'primary and 'secondary implementation of knowledge'.[8] According to Linn, the ability to operate with representations and models that forego reality is essential, and design as an activity through these means also deals with problems, or tasks, of action; series of situations during the process in which the architect must decide upon the best alternative. The role of the model is to in an abstracted way provide a context for such decision by bringing in relevant factors from the real world. When such tasks can be resolved according to existing patterns or methods they depend on 'secondary implementation' of knowledge, built on experience and tradition. When the task is regarded as "new" and requires thorough evaluation and analysis, as well as the development of new methods, the resolution requires

1 Nakazawa, Paul, course brief for 'A New Framework for Practice,' Harvard Design School, Fall 2007 http://isites.harvard.edu/icb/icb.do?keyword=k20453&pageid=icb.page100874 (1/8 2011)

2 See for example: Burke, Anthony & Tierney, Therese (ed.), *Network Practices: New Strategies in Architecture and Design*, Princeton Architectural Press, 2007

3 Sebastian, Rizal and Prins, Matthijs, 'Collaborative Architectural Design Management,' in Emmitt, Prins & Otter (ed.), *Architectural Management: International Research and Practice*, Wiley-Blackwell, 2009

4 See for example: Baker, Geoffrey H., *Design Strategies in Architecture: An Approach to the Analysis of Form*, Taylor & Francis, 1996

5 This view of schools of strategic management is based on: Mintzberg, Ahlstrand & Lampel, *Strategy Safari: Your Complete Guide through the Wilds of Strategic Management*, Prentice Hall, 2009

6 March, James G., 'Exploration and Exploitation in Organizational Learning,' in *Organization Science*, Vol. 2, No. 1, February 1991

7 Schön suggests that this is valid for many disciplines, but uses architectural education as a specific case. Schön, Donald A., *The Reflective Practitioner: How Professionals Think in Action*, Arena Ashgate Publishing, 1996

8 These terms are translated from Swedish by the author. Linn's original text in Swedish defines them as 'primär' and 'sekundär kunskapstillämpning,' Linn, Björn, *Arkitektur som kunskap*, Byggforskningsrådet, 1998

'primary implementation' of knowledge in the creation of a unique solution. Linn further suggests that artifacts and tools may operate in a guiding manner in regards to what knowledge is considered valuable, and what is no longer required. To a certain extent the developer of such tools can be seen as operating through a mode of primary knowledge, while the user of the tool would be operating through a secondary mode.

The different design and developer roles, and associated skills within digital design implemented in practice bring additional levels to these distinctions. Beyond the different techniques of digital design discussed previously (direct modeling, associative modeling and scripting), Robert Aish also suggests three different competences that may transcend the skills in technology. Geometric competence entails the understanding the language of geometry, and how to sequence geometric operations to achieve particular results. This may involve understanding the tolerances and computational efficiency of different geometric operations, or the ability to rationalize geometry in different ways. Algorithmic competence refers to the understanding of how complex problems can be decomposed into tractable states in a logical way, and how to recompose these states back into a consistent process. This is also crucial when an algorithmic process should be available to produce a series of different outcomes, and in re-use at a later stage. Compositional competence involves the understanding of how data is organized and handled, or complex relations between multi-purpose building components. This competence is vital when traditional subsystems of building systems are replaced by new assemblies that may cross disciplinary borders (between different sub-contractors for instance). These three competences are by Aish framed in terms of computational design, but he also suggests that they have a big impact on formal articulation, feasibility and efficiency in the resulting architecture.[9]

The implementation of new digital design methodologies in which formal and material innovation in the architecture produced foregrounds process efficiency, will inevitably still affect the design process. The formal characteristics in regards to procedural design development as discussed in the Reformations chapter further supports this argument, and the continuous technological development through which existing digital tools evolve rapidly and new are introduced, demands that processes need to continue to develop as well. It is not sufficient to resolve the steps of a design operation once and refine it for alternate project specific situations; the formation of project specific concepts as well as the transfer of knowledge between projects must also be approached. This adaptive mode of design requires continuous learning at individual, group and organizational levels. As the implementation of digital design technologies in architectural practice not only responds to existing problems, but rather to ambitions to search for new architectural solutions (which frequently provide new previously unknown problems), the single-loop and double-loop modes of learning introduced by Chris Argyris may provide valuable insight. The single-loop learning process regards daily activities in which routine and repetitive tasks are executed and refined in order to correct mistakes and improve quality, without interfering with the governing variables – the intentions of ideologies that motivate the task. The double-loop learning process requires those ambitions to be revisited, which in turn will affect other guidelines and systems directing work within a practice.[10] This brings the discussion of primary and secondary knowledge, and modes of exploration and exploitation, to an organizational level; operating through primary knowledge not only allows innovation in the singular case, it can also support organizational learning by affecting strategies and guidelines for practice in analogy with double-loop learning processes. Within digital design, a specialist within the field is frequently required to operate on the basis of primary knowledge, but over time routines and procedures may set the conditions for secondary knowledge implementation, useful for the specialist in future endeavors (such as the case of parametric design patterns and digital design tropes [Contexts II: p.24, p.41]). Technical innovation becomes intertwined with architectural ambitions. New architectural possibilities offered by technical advancement may change the condition for architectural development within digital design as well as within overall architectural project development. To the team external to the specialism, digital design development may always appear as implementing primary knowledge, but the development of reusable tools, for instance to automate parametric procedures through user friendly interfaces, may provide the non-skilled designer to employ them according to secondary knowledge modes. This transfer of digital design expertise into a practice may also further double-loop learning, through iterations in which such tools are updated, in effect operating as usable prototypes that undergo constant change.

This suggests the need for a discourse on the management of processes involving digital design techniques. Since innovative deployment of digital design techniques requires an understanding of technology as well as an architectural ambition that drives and exploits the development of such technology, this discourse needs to combine conceptual design thinking, architectural purpose, client interests as well as an understanding of technological opportunities as well as limits. In order to achieve a change of processes and link between management levels and operational levels, the inclusion of both long term process development (and its goals) as well as short term project development (and how it can both benefit the targets of the individual project and be part of the long term development) is essential. In short, there is a need for strategic management suited to the context of digital design methods in architectural practice in order to deploy digital design techniques within projects in relevant, innovative and reliable ways.

Furthermore, if early CAD procedures follow the tradition of previous modes of architectural design, or even a misinformed understanding of the design procedures within architectural practice[11], the introduction of parametric techniques is a break from this. Jeffrey Kipnis argues that most of the great achievements of this time may even be seen as counter intuitive, which makes further development difficult since most of the world outside architecture would like to define architecture to be intuitive.[12] There is a need to add an additional layer of mediation between general designers and digital specialists, in order to bridge the gap that may arise due to differentiation of tasks (between general designers and specialists), generational differ-

ences (advanced computational skills versus long experience) or different aesthetic ambitions. This mediation depends on a readiness to incorporate new digital workflows in a way that both supports design innovation and facilitate rational design processes, and it must enable such aspects in specific short term project situations as well as in long term organizational development.

Architectural practices that have been founded with new digital methodology as an important asset faces these challenges as they interact with other parties in the construction industry, and as they mature and grow they most likely need to reassess methods, workflows and processes. Practices that have not evolved within the digital design paradigm have the opportunity to make use of prior knowledge and skill in the formation of new design strategies that respond to needs and opportunities within the existing work flow, while also invigorating those with new potentials. In order to support the inclusion of "new" digital design techniques within an existing organization, there is a need for strategic formulation of the modes of operation for the implementation of new design thinking into traditional workflows, which in extension will change those workflows. The formulation of digital design strategies may augment and formalize design development at several levels, while still introducing new venues for innovation in process and result. They do not only implement already developed methods and techniques, they also help formalize and repurpose techniques that have emerged in experimental practice as they are entering regular practice, which will lead to a re-evaluation of the same techniques. Within the digital design field, this entails a continuous shift between primary and secondary knowledge implementation, as well as modes of exploration and exploitation. As digital design methodologies are introduced in general architectural practice, they can also further enhance the capacity to reflect-in-action, enabling design teams to probe and redefine design problems through a number of iterations of versions, with the support of fabrication and performance evaluation. As digital techniques are repurposed, the architectural designer brings the notion of tool builder to another level; not only is it necessary to have a technical expertise and a conceptual understanding of tools and design approaches as seen in experimental practice over the last decades, it is also necessary to grasp managerial issues and ways to orchestrate changes in work flows and behaviors of employees. The development of parametric and associated systems requires resources of skill and time however, and needs to be deployed wisely. A parallel to the ongoing adoption of BIM work flows, digital design strategies entails the formalization of conceptual design thinking as well as rationales for its implementation with a strong base in architectural innovation; not only a rationalization of work flows and data management, but also an incorporation of formal and performative potentials beyond the immediate need in current work flows. A distinction can be made between strategies for development, deployment and project specific situations. At the development level, these strategies identify relevant territories that include both architectural elements and particular process steps. At the deployment level the particular potentials within a practice is considered in order to find opportunities, which relates to employment expertise, architectural ambitions and client concerns. At the project specific level, relevant strategies are selected depending the conditions given by the project, and are given specifications such as formal agenda or programmatic purpose. As new project specific strategies are developed, lessons learned must also feed back into the other strategic levels through a managerial mode of double-loop learning.

Summary:

- The integration of digital design methodology, prototypical approaches and formal innovation into general architectural practice has an effect on the nature of knowledge generated and implemented, and will influence the process due to resources needed and results gained. It will depend on the development of specific digital design strategies.

- Strategic management of digital design specialisms within a practice can potentially facilitate single- and double-loop organizational learning within specialist teams as well as between those teams and the overall practice.

- Digital design strategies are suggested to operate at three levels; as development, as deployment and in project specific situations.

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9 Interview with Robert Aish in London April 2009, published in Swedish in: Runberger, Jonas, *Arkitekters Verktyg*, Arkus 2012

10 Argyris, Chris, *On Organizational Learning*, 2nd Edition, Blackwell Publishing, 1999, p. 68 – 71, 151 – 152, 409 - 410

11 Örjan Wikforss suggests that early CAD-development was based on the apparent focus on construction drawings within architectural practice, neglecting traditional modes of sketching and design development. Wikforss, Örjan, *Informationsteknologi tvärs genom byggsverige*, Svensk Byggtjänst, 1993

12 Jeffrey Kipnis commented on this in the open debate on Schumacher's recent publication at the Architectural Association, in response to Schumacher's claim that he needed to re-train himself in order to understand and value the new potentials of digital design. http://www.aaschool.ac.uk//VIDEO/lecture.php?ID=1517 (31/7 2011)

The Field of Strategic Management

There are different perspectives on strategic thinking, which affects the way in which strategies are formed. In the rational perspective, logic reasoning is crucial, and the strategist is preferably trained in a scientific tradition.[13] In a generative reasoning approach, emphasis is placed on wicked problems [Contexts I: p.17] and creative interpretation of a problem situation and to challenge the given solution.[14] A mix of these two approaches seems inevitable for an informed, clear and innovative strategy to be conceived, but there are several other oppositions, or paradoxes identified within strategic thinking. The formation of strategies may be seen as deliberate or emergent, the strategic change induced may be revolutionary or evolutionary, a business may be driven by markets or resources and face competition or be in cooperation with other business in a network, a market may be local or global and on organization may balance profit with responsibility.[15] In large organizations there is a need to divide management into a hierarchy of strategic development at different levels. A 'corporate level strategy' is an overarching framework for diverse business with several different business segments, and involves the creation of synergy between those segments. 'Business level strategy' regards a single business unit in such a corporation, or a single firm, and coordinates lower level strategies into a coherent whole. 'Functional level strategies' are developed for each functional area, such as marketing, human resources, product development or R&D, and may include various sub-strategies to further align different aspects of the practice. The further breakdown into operational strategies focus and deal with daily operational activities and is strongly controlled through the upper level strategies. Most strategic situations consist of three different aspects – 'strategy process,' 'strategy content' and 'strategy context'. The 'strategy process' involves the process in which strategies are formed, as part of an ongoing process rather than as a strategy as a static definition that can be re-deployed continuously. 'Strategy content' is the product of this process, and depends very much on the level on which the strategy is meant to be deployed. An activity system integrates different value adding processes and is an important basis for competitive advantages, and can include activities such as operations in which inputs are transformed to products and services and technology development of products and processes.

The inherent competences can be distinguished into knowledge (rules and insights extracted from information), capability (narrowed down and specific skills of individuals and the organizations ability to combine those skills) and attitude (prevalent mindsets within an organization, both temporary ones and more importantly characteristics that are long term, such as being quality-driven, internationally oriented, innovation-minded and/or being competitive). While the understanding of the current resources of an organization is important, it may be even more important to understand the resources (in particular intangible ones) within the competition. 'Strategy context' refers to the situation in which both process is developed and content is to be deployed, and the crucial is here how an organization can go from adapting to actually shaping that context. This also includes an understanding of the competition, and the field in which an organization operates. At a business level, there may be a move towards convergence (in which the business models of different firms are very similar) or towards divergence (in which different organizations strive to compete on different basis). There may be many different drivers for changes in an industry, including socio-cultural (such as environmental awareness and consumer interest), economic (such as economic growth and labor productivity), political (such as regulation and legislation) and technological (scientific breakthroughs and technological innovation), and change is often induced by a combination of these factors. There are also several inhibitors for industry change, such as power structures (in which powerful actors have little to gain through change), risk averseness (where actors are unwilling to take risks) and industry recipes (where there is a mutual informal agreement of the rules of the game).

The creation of a strategy is known as strategy formulation, followed by strategy implementation. When a strategy is refined or changed through evaluated performance or changing conditions, it is known as strategy formation, an ongoing activity that follows the previously mentioned stages of identification, diagnosis, conception and realization. Key issues here involve how formalized the actions to be taken by participants are, and who is involved in the formation process. In a larger organization with many participants the process may need to be highly formalized and controlled by actors at different levels of the hierarchy, with decision making on important issues being made at the top level. This approach is good for all those activities that can be regulated and documented, but may not benefit learning and innovation.

If the business model level of the strategic context is applied to the functional strategies for ICT and digital design methodologies within architectural practice, the development of BIM can be regarded as moving towards convergence, due to the need for industry standards and common processes within projects as well as within the industry at large. Many practices are using BIM as an argument for best practice and such expertise is therefore also potentially a unique asset for competitive purposes, but the ambitions to establish standards within the industry are essential in order to fully exploit such assets. Within the digital design field, especially in the most advanced practices, unique applications of new design methodology are important assets, and may even provide the most important identity to a practice. To certain extents this suggests a trajectory towards divergence, in the sense of unique application of similar methodologies. Within a larger context of general architectural practice, the use of digital design methodologies also provides unique opportunities. In parallel the thriving communities that have emerged in relation to the digital design field is driven by exchanges of ideas and presentations of innovative solutions, but also here the value lies in providing new applications of digital design, rather than providing solutions for standardized workflows or general models of best practice. The different drivers for the change that is underway within architecture and the building industry may further differentiate the fields of ICT and digital design methodology, although there are of course many overlaps. Economic drivers are crucial for BIM and process development that look for control of quality and the flow of information, but coupled are

of course also technological innovation and environmental concerns. The digital design field certainly includes the ambition to develop sustainable solutions within economically viable frameworks, but it is the renewed interest in more articulated spatial expressions and new programmatic potential in combination with technological advancement that function as key drivers. This entails including explorative modes of practice, and the continued generation and implementation of primary modes of knowledge. This can only be facilitated on a long term basis through a strategic understanding of the benefits of such development, and organizational learning.

In reference to the notion of digital design strategies the functional and operational strategic levels are of most relevance. It is preferable that a functional level digital design strategy is aligned with an organization's overall business strategy, but on the other hand it would be further supported by other levels. The early development within the digital design field can be regarded as emergent in terms of strategic formulation, and content wise focused on very particular issues such as formal design and fabrication. The introduction of these methodologies into existing practice would require deliberate formulations of strategies that take the organization of the specific practice in mind, and extends the issues involved from a limited experimental situation into selected parts of a full scale architectural project. The strategic levels of digital design could be seen as guiding the implemented methodologies, which in turn would be coordinated in the form of activity systems. Within architectural practice, except perhaps in the case of very large firms, there is a tendency to operate on a more informal level, as a result of traditional notions of architectural practice as well as the strong focus on project development. In the case of digital and parametric techniques, they require a more formalized design process as well as an informal understanding of the opportunities offered, and in this way they require strategic management beyond the project situation. The activity systems of implemented digital design include routines and modes of practice involving digital design methodology, as well as guiding principles for continued development and knowledge management. As with the strategic perspective of the rational versus the generative perspective, there is a need to balance the formal and informal aspects of these strategies, and the level of formalism of the processes and techniques involved. With different requirement between projects and the continued technological development, they also require a model for strategy formation, in which specialists and non-specialists take part in the evaluation. Since the formulation of a single overarching digital design strategy that suits any scenario would be too general to have relevance in daily work, operational strategies may have to be formed as part of projects, based on a framework or template. The potential re-use of these operational strategies, as well as internal non-project-specific development can be managed on the basis of functional digital design strategies.

Summary:

- For the purposes of this thesis, digital design strategies will due to the requirement of continued development be proposed on the basis of strategic management rather than project management principles.

- Strategies will be discussed at the functional and operational level, and will acknowledge both emergent and deliberate aspects, and the implemented methodologies can be regarded as core techniques for digital design activity systems.

- Due to changing conditions and technological advancement, digital design strategies must regard issues of formulation as well as formation.

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13 The general understanding of strategic management that follows is primarily based on: De Wit, Bob and Meyer, Ron, *Strategy: Process, Content, Context*, Thomson Learning, 3rd Edition, 2004 and http://en.wikipedia.org/wiki/Strategic_management (4/7 2011)

14 De Wit, Bob and Meyer, Ron, *Strategy: Process, Content, Context*, Thomson Learning, 3rd Edition, 2004, p.62

15 Ibid., p.111

Organizational Learning and Digital Specialisms

The development of new specialisms within architectural practice involve many fields, including project management of projects that employ BIM, advanced ICT support for general project development employing BIM approaches, environmental specialists and teams with skills that allow the development, management and implementation of digital design methodology. With new specialist teams becoming part of the architectural design teams there are new challenges for organizations to manage many different skill sets, but also new opportunities for knowledge production. The digital design field advances the traditional way of producing architectural knowledge through the establishment of models that go beyond representation, through which project specific knowledge is created through interactions between the model as construct and architects, and other disciplines. Advanced digital models, in particular parametric or scripted systems, depend on specialist designers in order to be established, developed and managed. As digital prototypes, these models allow analysis and testing that could be related to the tools of the trade of the structural or environmental engineer, and the complexity of operations both deliver in-depth knowledge and requires skill built up over time to manage. It can be related to engineering an innovation that resolves advanced problems, but also informs and enables new problems to be defined early in the design process.

The conceptual space formed around advanced digital tools, is what allows architectural innovation in conception and delivery, but the dependence upon specialists may also demand that new environments emerge in-between the traditional roles of designing architects and problem solving engineers, in which specific design cultures are established. These en-vironments of digital design specialists may be intentionally formed within a practice, but they may also consist of members distributed across different practices and within academia; channels through which knowledge is generated and disseminated. While they often are part of communities external to the organization in which they were formed, they may however encounter difficulty in being completely integrated into workflows and practice culture of that organization.

Even though digital design methodology is founded in technology that provides modeling features that are exact, the continued progress of the field depends on sharing of knowledge and skills, but also the continued build up of discourse and conceptual understanding. Within the field of management, the terms knowledge management and learning organizations have been used for a long time, and in some cases have come to challenge previous notions of strategic planning.[16] While there is a strong relation to technology, in the sense of technical systems that allow the archiving and exchange of information, the important role of social networks (not only the on-line ones) is recognized as a crucial aspect for any organization. Etienne Wenger has introduced the idea of 'communities of practice,' informal and pervasive networks that are integral parts of our lives and may seem obvious, but when explored systematically, may be useful to understand learning and innovation within an organization. Communities of practice are in this sense not necessarily formal organizations; they could be networks that share a discourse, or they could be smaller groups within a formal organization. The notion of practice that he introduces is not in opposition to theory; in fact a community that specializes in the production of theory is in itself regarded as a practice. A number of factors are critical to these communities; there is a negotiation of meaning and participation, there is mutual engagement and a joint enterprise, and there is continuous learning and development providing a shared repertoire.[17] When Wenger identifies actors engaged in participation, he eliminates non-human actors, based on the idea that mutual recognition is important for participation. He does recognize other theories that would allow non-human actors, such as the Actor Network Theory of Bruno Latour, but suggests that this is based on an interest in seeing all actions as part of one total system [Contexts I: p.55]. Wenger's interest is in meaning and learning, and the mutual ability to negotiate these. In response to this, he suggests the term reification as a production of abstractions with meaning, including representations that become part of our work and change the nature of that activity, and our experience of the world. Though it may refer to both process and product, the abstractions themselves can have been produced elsewhere and then integrated into the community. And further, it does not necessarily result in the design of something and it could take many different forms. Of most importance is however that they represent a larger context of significance and that the processes by which they are integrated into a practice also affect their characteristics. The relation between reification and participation is seen as critical – too much reliance on one over the other is likely to be problematic in practice. If participation prevails, and there is no reification, there may not be enough material to reinforce coordination or uncover diverging assumptions resulting in a too informal environment. If reification prevails, with little opportunity for shared experiences and interactive and direct negotiation, there may not be enough overlap to recover a coordinated, relevant or generative meaning, resulting in an overly formalized environment.[18]

While many of the aspects of a community of practice are internal and set within a local context or boundary, this boundary can be blurred in a number of ways. Boundary objects are artifacts, documents, systems or tools that are reificative, but use this characteristic to bridge separate forms of participation. They become vessels for interaction, or set standards through which the activities within one community can be related to the world. They can be characterized through being modular (which allows different parts to be accessed by participants of different perspectives), abstract (with only features common to all perspectives present), accommodative (lending itself to different kinds of activities) and/or standardized (which allows each user to recognize and understand how to operate it). There may also be people with multiple community membership, who transfer elements between them through acts of brokering. The broker would need to translate, coordinate and align between different perspectives, but if successful he or she could open new possibilities for meaning. At the same time the broker must avoid being pulled deep in to become a full member of any community, as well as being regarded as an intruder. There are also boundary practices that

could emerge within official organizations. They may trespass the boundary of other communities, or be spread out within an organization, such as a network of specialists that belong to different departments but stay in good contact. Peripheries are related to boundaries, but rather than being discontinuities, they indicate areas of connection, such as venues where external parties may get partial access to an otherwise closed community.[19]

Identity and modes of belonging are important concepts for the kind of practices discussed by Wenger, and there are several factors that are involved here. Engagement, accountability and negotiability are paramount, and regard in turn how members interact and work together, how our investment in an organization affects our perspectives on many different things, and how a sustained engagement in practice allows us to interpret and use the repertoire of artifacts, actions and language of that community.[20] Engagement can also be seen as a particular mode of belonging, which includes an ongoing negotiation of meaning (through reification and participation), formation of trajectories (by which the direction of the constant change of a community is affected by internal and external contexts and events) and a continuous unfolding of the histories of a practice (in which the history of the practice is continuously communicated through the interaction between older and younger members). Beyond engagement, Wenger also suggests two additional modes of belonging. Imagination refers to the creative ability to extrapolate from one's own experience and thereby creating distanced, alternate images of what could be. Alignment entails the coordination of individual actions into a larger enterprise, and is related to power, for better or worse. Most activities involve a combination of engagement, imagination and alignment, but an emphasis on one or the other affects actions and meaning, and the reason for a focus on a particular mode depends on local conditions and the types of work conducted. Engagement is focused on a shared practice, with access to other participants as well as strong support of reificative symbols, tools and documents. Typical processes include the definition of a common enterprise, mutual engagement in shared activities, an in-house regime of competence, the development of interpersonal relationships and the management of boundaries. Imagination requires an ability to disengage and temporarily distance oneself from engagement, taking risks and create unlikely connections and thereby dislocate participation and reification to open up for innovation. Typical processes include locating engagement in broader contexts, sharing stories and descriptions, opening access to distant practices, creating models and extrapolating into the future by understanding the past by the generation of scenarios of alternate modes of operation. Alignment depends on the coordination of perspectives in order to direct efforts towards a common purpose, and relies on the ability to communicate purpose, needs, methods and criteria. Typical processes include negotiation of perspectives for common ground, imposing of one view through power and authority, defining broad visions, devising procedural and quantitative control structures and creating boundary practices.[21]

Wenger further argues that communities of practice relate to learning in two main ways; on the one hand the engagement and identity support acquisition of knowledge, on the other hand it can also provide a good context in which to explore new insights and thereby becoming a platform for the creation of knowledge. Combinations of the three modes of belonging are essential here. Engagement and imagination result in a reflective practice, that combines the ability to engage and distance, where the engagement mode allows visionary imaginative approaches to be "negotiated in practice and realized into identities of participation." The combination of imagination and alignment provides the ability to operate with respect to a broader context, by situating a vision into action. The alignment can be very robust since it has been formed in a critical context. By combining engagement and alignment different perspectives are brought together, and the coordination of mutual engagement provides opportunities to explore relevant boundaries, while a negotiation of alignment in relation to a diverse field of engagement may lead to a redefinition of an enterprise. The combination of modes depends not only on overlap, but also on timing; different combinations may be appropriate at different times of the lifespan of a community.[22]

For Wenger, communities of practice are not new, and they exist in many different forms, inside or outside of formal organizations. They can be recognized, encouraged and nurtured, but according to him, they cannot be designed, or formed through strategic management. One can design work processes but not work practices, one can design systems for accountability and policies but not the practices that will emerge.[23] Furthermore, while communities of practice are key to an organization's competence and evolution, they differ in that they negotiate their own enterprise (but may conform in response to institutional directions), they arise, evolve and dissolve according to the aspects and modes explained (which may be in response to institutional events) and they shape their own boundaries (which may be aligned with institutional boundaries). In effect, an organization is seen as a meeting of two sources of structure; the designed structure of an institution (based on organizational models, strategies, policies and formally described procedures) and the emergent structure of practice. Their relation is one of constant negotiation.[24]

Architectural representations are by nature reifications, and in many cases boundary objects, in the way they are employed by architects in daily practice – and serve as communicative protocols between different participants in projects. The models employed within digital design further advance the reificative characteristics, in that they document design decisions within the process and become re-used as instrumental devices. As

16 Organizational learning is also associated with organizational culture, both of which must facilitate 'perpetual learning' in the rapidly changing contemporary situation. Argyris, Chris, *On Organizational Learning*, 2nd Edition, Blackwell Publishing, 1999
17 Wenger, Etienne, *Communities of Practice, Learning, Meaning and Identity*, Cambridge University Press 1998
18 Ibid., p.65
19 Ibid., p.103 – 121
20 Ibid., p.152
21 Ibid., p.173 – 187
22 Ibid., p.214 – 221
23 Ibid., p.228
24 Ibid., p.244

boundary objects they connect different communities; the practices and organizations in which they were created and the different on-line communities and venues that belong to the digital design field. As equally important within architectural and engineering practice they are promoting new ways of sharing knowledge and meaning between disciplines. Furthermore, the relations to fields such as computer science provide bridges to other scientific fields, which has led many specialized architects to go beyond the disciplinary field of knowledge. This enables new the emergence of new networks between practices, in the way Wenger describes peripheries.

The role of the broker within the digital design field is multiple. To a certain extent, each individual that employs digital design skills within practice or within education as a student, and also participates in any of the networked communities is brokering agendas, knowledge and skills between different environments. Digital design patterns developed within one community are also frequently spread to others, through the formal qualities of parametric design definitions. The boundaries that need to be bridged are not necessarily only the formal ones between different practices, academia, and informal on-line communities; there may be greater boundaries within a practice, or within an academic context. Internal existing design workflows formed through habit and individual preference may offer resistance to the implementation of new methodologies, but can also provide a context which may influence and bring new agency to the digital design field. Proprietary issues in regards to specific design patterns developed within a practice may limit the dissemination of new knowledge to a wider context, limiting acts of brokering. The differentiation into different specialisms, including those of the digital design field, may result in the emergence of different organizational cultures which in turn may limit communication and the formulation of common strategies.

The opportunities to collaborate within specialist teams, as well as the sharing attitude within digital design communities, contribute to the aspects of belonging that have been essentially for the emergence of the digital design field. Imagination and alignment as modes of belonging have also been crucial as drivers for the field, but can also be seen as slightly problematic in the maturing field that becomes integrated in practice. Alignment in regards to different drivers and agendas has always been multiple, as discussed in the Reformations chapter, but as digital specialisms are integrated into practice they also need to be aligned o the specific modes of practice. The future needs for the digital design field may very well require all three of Wengers suggested combined modes of belonging in order to continue an innovative development. Engagement is critical to the field, in the sense that commitment is necessary to take on the challenges offered by learning new and advanced computational techniques. Imagination might here entail the ability to distance oneself form the inner workings of the digital methodology, and find new opportunities within the framework of conventional practice, which in order to achieve agency requires a certain extent of alignment to that practice. Alignment can also be an issue for the digital design field in general, but Patrik Schumacher's ambitious project and the critique following it suggest that there must be multiple trajectories [Contexts II: p.48]. The most critical negotiation may be between engagement and accountability, as the previous free experimental scene must align to modes of practice that may be regarded to add restrictions previously not present.

The primary aim of strategic management is to increase efficiency and improve profit, and while this involves continuous development and the establishment of an adaptive organization, there is a risk of being over-zealous, which could lead to an organization that is not prepared for new challenges, and does not use its resources in a way that facilitates innovation. The concepts defined as part of the communities of practice are focusing on the learning organization, and how informal potential can emerge within organizations if nurtured properly, but in order to innovate there is also a need for a direction. In both systems of thinking, objective becomes important, either as the organizational purpose or through negotiations between engagement and alignment. The discipline of architecture combines a service-oriented profession with a conceptual (and sometimes academic) discourse, and internal processes of knowledge management are as important as a framework to support innovation, a formalized design process in regards to other industry actors and a strong connection with society. Early stage design development, of particular interest for the setting up of a framework for the generation of values in an architectural project, is a part of the process that has only recently been explored, and that is still rare in the discourses on digital design. While a thorough analysis and previous knowledge is crucial for a well informed project process, there is in most projects a need to act innovatively and speedily. There is no way to do full research on all aspects relevant to the design, and many aspects are unknown. As strategic management has formed theories and ideas in regards to planning and organization, and Wenger's notion of communities of practice investigates the social interplay within and between formal organizations, Schumacher's notion of a unified theory seeks to structure the organization within the discipline of architecture. The notion of the discipline exists in both practice and academia; Schumacher suggests that it includes artifacts (buildings), knowledge (the academic realm) and practice (the professional activity directed towards the production of artifacts) [25]

Summary:

- Digital design methodologies can be regarded as instruments for reification as well as boundary object, and can as such support organizational learning, inter disciplinary collaboration and connections between formal and informal communities.

- There are multiple modes of brokering that are critical to the digital design field; between informal communities and specific practices, between specialist teams that may be regarded as communities in themselves and an overall practice, and between teaching and research in academia, and informal communities and practice.

- Wenger's notion of modes of belonging has great relevance for the emergence of the digital design field, but also suggest potential challenges in future implementation, in particular in regards to retaining experimental qualities while aligning

development to practice. His notion of belonging through the mode of imagination suggests that the speculative approaches discussed in the previous section also can be beneficial to practice culture.

Strategies for Parametric Design Implementation, a reference

Roland Hudson expands the categories of tasks introduced previously, and outlines a number of strategies guiding the parametric designer involved in architectural projects [Contexts II: p.23]. The findings and propositions of his 2010 PhD thesis are mainly based on his own experiences as a parametric designer involved as a consultant in a number of projects, including an arena and several tower projects.[26] Hudson's role within these projects, as well as his experience as a tutor for Bentley's GenerativeComponents application since 2005[27], sets the condition that problems can be defined as a premise for parametric design provided that the nature of the architectural problem is understood. He further defines five strategies, of which one is aimed at cases in which the design problem is unknown, and the remaining represent different stages of design development from capturing design intent (of the general design team) to the sharing of information and final documentation to other participants in the process.

The strategies defined by Hudson are defined through their location in the digital design process, as well as the conditions of the particular project. The 'Model construction strategy' relates to the externalization of ideas through the development of parametric models. The 'Knowledge Development strategy' is used when the design problem is unknown and employs the definition of parametric models to externalize ideas. The 'Knowledge capture strategy' is intended for situations where a problem description is already known, when there is design intent and the issues for the parametric development are well defined. The 'Design investigation strategy' involves generating a design and testing it against previously defined problem descriptions. The 'Construction documentation strategy' is aimed at situations in which information needs to be shared between different members of the construction team. In this way, Hudson maps specific conditions and tasks relevant at different stages of the process particular to digital design endeavors.

Based on his findings in literature, references and his own work, the five strategies are distributed over a so-called task structure, divided into classes of tasks and associated with sub-tasks and procedures that further define potential actions to be taken. The act of establishing a parametric model should be initiated early and tested immediately, to allow that an incremental development should be anticipated from the start. Parametric relations should be considered prior to form, and the 'propose – critique – modify' methodology presented earlier is applicable in order to find a suitable principle from modeling [Contexts II: p.23]. An important basis for his argument is the presumption that design problems can be formalized, but he also proposes diagramming for an initial understanding and assumptions to fill in any gaps. This could entail that a problem (and consequently the model) needs to be fragmented, such as an initial study of more schematic building elements for later refinement.

Hudson indicates that his five strategies are intended as frameworks for "high level planning" of practical parametric design processes, to be informed by any given situation. In implementation, the strategy is seen as dynamic and subject to change due to circumstances. Although it may not be possible to know the extents of parametric development in the outset of an architectural project, Hudson still emphasizes the importance of indentifying at which design stage a parametric strategy may be employed. A short term view of the involvement suggests that immediate problems are tackled without regard for later issues, which may allow for a freer exploration and still provide important cues for later development. A long term view suggests more extensive strategic planning with a combination of four of the suggested strategies (depending on the choice of Knowledge Development or Capture). The extent of involvement also depends on the position of the parametric design team, and an enforcement of BIM workflows may restrict the possibilities of information exchange.

A number of procedures are given more attention by Hudson, in a way that can further clarify the territory of digital design he is exploring. 'Post-rationalization' of geometry is employed when the initial design has not taken issues such as structure and fabrication into account, and a viable geometrical solution needs to be matched to the design intent. In 'pre-rationalization' the rational geometrical principle is already suggested in the initial design and focus lies on detail design and fabrication. The 'fragmentation' of design problems, tasks and modeling processes involves partitioning the tasks into smaller parts that are more manageable, providing a better understanding of the problem description and allowing non-specialist team members to take responsibility for parts of the model. This compartmentalization of problems and tasks depends on the designer's experience of the particular design problem, and there are usually multiple alternatives for how this can be achieved.

Hudson's thesis is founded on theoretical research, descriptions from practice informed by his experience as a parametric designer employed in a number of projects as well as interviews with leading practitioners within the field. The task structures and strategies suggested are therefore well founded, and give a comprehensive overview over certain aspects of parametric design in some of the most advanced practices today. They depend however on a design intent that is deemed to benefit from parametric design based on experiences from similar projects; primarily buildings based on a complex geometry that would be produced through a mode of structural evaluation, breakdown

25 Schumacher, Patrik, *The Autopoiesis of Architecture: A New Framework for Architecture* Vol. 1, Wiley 2011. p.1

26 Hudson, Roland, *Strategies for parametric design in architecture: An application of practice led research*, PhD Thesis, University of Bath, 2010 Available here: http://opus.bath.ac.uk/20947/1/RHudsonEThesis.pdf (8/8 2011)

27 Coincidently, the author received his first introduction to GenerativeComponents by Roland Hudson in 2005, facilitated by Bentley for the members of the Krets research group.

of surfaces into panels, and possibly prefabricated elements to be assembled on site. Even if he has the perspective of the parametric designer in mind, there are few suggestions for open ended innovation where computational techniques become the driver for architectural issues beyond rationalization of a given overall form and the articulation of details. The innovation that would be inherent in the task structure provided would most likely lie purely within advanced development of parametric associations, the ability to take on even more advanced forms, or the potential to provide more intelligent models for evaluation and manufacture. The approach may be aligned with current modes of practice, where the value added is the high quality execution of formal concepts conceived in the design team. In essence, they provide a formalized understanding of recent developments in cutting edge practices, which of course is a valuable contribution to practice and research alike.

From the perspective of the emergent communities of practice described by Wenger, one can note that Hudson speaks very little about non formalized exchanges which may be due to the fact that parametric design is technology intensive. The cases he bases his thesis on are restricted to projects in which the overarching design task is easily identified and the proposed task structure and strategies by necessity and intention are quite formalized. There are a number of interesting observations to be made however. Hudson does not in detail describe the parametric technologies that are fundamental to parametric design, instead he puts his focus on the definitions of design problems, tasks, considerations (that are situational) and strategic approaches to all of these. The parametric tools, the design methods and the tasks can all be seen as reifications. To use Wenger's term; software is defined as extreme reifications which suggest that the parametric system which is continuously being constructed, executed and evaluated is even more so.[28] The process of problem development and description through the means of diagramming, multiple representation and parametric system development are all acts of reification, in that they facilitate control over very complex situations. The relation between participation and reification are of particular concern to the participatory aspects of parametric design; Hudson does indicate that verbal communication is important, but he does not advocate a build-up of meaning, beyond the understanding of initial design intent (which does rely on a combination of representations and verbal communication). The notion of boundary objects is also of particular interest, in their potential to bridge separate forms of participation.[29] Boundary objects are in play at several levels within parametric design development. They are first of all systems that are aimed at making implicit design intent explicit (crossing the boundary of implicit and explicit). This is an important prerequisite for the second level; the communication between the architectural design team and other parties, especially in the malleable aspects of the parametric model which provides an accommodating character. They also set the parametric design team in relation with the global communities that have evolved around parametric technology, methods and concepts, and admit this network into the realm of the practice. This also entails that a parametric team internal to an office may operate as a boundary practice, which is quite apparent in many of the parametric design conferences that see participants from a range of firms. In this sense a parametric designer may also become a broker, although he or she most likely has a primary allegiance to the office of employment.

Summary:

- In specific situations in which there is an identifiable opportunity or a given task for parametric design, it is possible to develop framework strategies based on a generic task structure, with specific task classes, sub-tasks and procedures.

- Parametric models can be employed for knowledge capture that refine an initial design, or knowledge development, in which design problems are developed and made explicit through communication with design team.

  Fragmentation of design problems, tasks and modeling processes can be used to partition a complex project into manageable parts that also may allow non-specialists to take responsibility for parts of the model.

- Wenger's terminology can be applied to different aspects of parametric design strategies, in particular in regards to participative modeling and in making design intents explicit.

Digital Design Strategies

As discussed in the previous sections, the integration of digital design methodologies, prototypical approaches and formal innovation into general architectural practice can be benefitted by the establishment of digital design strategies. This can further enable different modes of organizational learning through strategy supported practice as well as an understanding of formal and informal organizations. The digital methodologies involved can be regarded as tools not only for design, but also for organizational learning as well as boundary objects that can facilitate exchange of knowledge between different organizations and communities. The strategies are expected to work at functional and operational level, and need to take both formulation (initial development) and formation (continued re-development) into account. The role of the broker is of particular interest, in facilitating communication within specialist teams and an overall practice, as well as between a practice and other formal and informal organizations. In particular well defined situations, strategies can be formulated according to specific task structures,subtasks and procedures, but then depend on capture of design intent. Fragmentation of design problems, tasks and modeling processes can be used to partition a complex project into manageable parts, facilitate such strategies, and can also enable collaboration between specialists and non-specialists.

On this basis, the ambition in this chapter is to propose comprehensive digital design strategies that may support digital design integration in situations that are previously well documented, but also can facilitate a framework that extends such integration into other domains. These are not necessarily completely new or unique applications of digital design methodologies, but aim at giving opportunities to take the context of conventional architectural practice as a venue for continued exploration in this direction. The formulation of the strategies will further employ project examples presented in the two Project books of this thesis.

Comprehensive Strategies for Digital Design in Architecture

The intention here is to define strategies that are comprehensive in the sense of being adaptable to different aspects of an architectural design project, rather than to suggest an excessive formalized design process. The objective is furthermore to move beyond a problem solving approach, and instead regard the use of digital design techniques as drivers and facilitators of the design process. There may be cases in which knowledge capture of design intent external to the digital design process is required, but primarily project specific issues are relevant as a context for the digital design development itself, and design intent is regarded to be formed as part of this development. This approach makes the digital design strategies implied less susceptible to generalization at least at operational level.

If one regards the digital design field as a specialist field in which design methodologies put new demands on processes as well as bring in new potential for architectural qualities, it is even more important to regard the role of new skills and knowledge in relation to a more traditional mode of architectural design and production of knowledge. A primary feature of digital design techniques is the possibility to associate different parts together, in effect to build systems of related elements that could range from geometries, data sets or processes that can be formally modeled. This does not entail that they allow a design to be pre-programmed in a way that makes a solution the only answer to a given problem; to the contrary they are flexible systems that allow a designer to interact and get feedback on design ideas. They are also not neutral; while they could be deployed without any particular bias towards formal design, they are particularly appropriate to use for investigations of more complex form, and the discourses that have emerged around them are often related to the performance of form, be it from a technical or aesthetic perspective. The design strategies are not only an aid in finding appropriate applications to existing techniques; they should also provide a link between implementation, development within practice and development within academia and informal communities.

While the technical platforms on which parametric design thinking relies might suggest that they can be defined in concordance with the overall IT strategy of a practice, and be managed through a mode of IT management, the strong integration between design thinking, architectural discourse, conceptual development and technology dependence suggest that an alternate approach is necessary. An architectural practice with a strong design identity often evolves a sense of community based design methods and modes of architectural discourse that go beyond both technological expertise and organizational management. It encompasses a particular mode of belonging and identity, comparable to Wenger's description of an ongoing negotiation of meaning. In extension, for such a practice to continue to evolve, it depends on his notions of imagination, alignment and engagement. The continuous introduction of new technical expertise into such a practice requires reflection, and the ability to situate vision into action. The overall strategic ideology behind the integration of advanced digital design principles and the framework that allows the continued development and deployment of digital design techniques in an integrated (to the overall practice) and strategic way, is in this context referred to as a comprehensive digital design strategy. The comprehensive design strategy regarded as a functional strategy focusing on a very particular expertise can provide an advantage from a competitive perspective. Operational strategies that in turn supported digital design

28 Wenger, Etienne, *Communities of Practice, Learning, Meaning and Identity*, Cambridge University Press 1998, p. 60

29 Ibid., p.106

development, can be related to activity systems that integrate different value adding processes (such as conceptual design integrated with technological prowess).[30] The strategic context of the comprehensive design strategy needs to bridge between the fields of Research & Development (where strategies can be formulated), IT methodology (which provides an access to other IT based development trajectories such as BIM) and project development (the primary activity of most architectural practices).[31]
As the digital design field is in rapid development, there is also a need to connect to parties external to the practice, such as professional bodies, interest organizations, academic research and individual specialists. This is in particular important since the development of digital design in practice has been primarily driven by technological innovation and social-cultural tendencies within the discipline, rather than through consumer demand or market advantage (so far). In an international context, advanced digital design has become a major asset in a large number of projects in the global arena, while the practices behind those projects typically have been very active in digital design communities globally as well in their local context. From a Swedish perspective it is important to remain in close contact to international actors, but also continue to promote the establishment of a local community within the discipline of architecture.

If the digital design development environment within a practice is considered an activity system, with specific types of knowledge, capabilities and attitude, it can be seen as the framework in which the comprehensive strategy is formulated and implemented, and where strategic formation is facilitated. The relation to general R&D activities can allow for continuous development within a practice, including knowledge management, method development and dissemination to all relevant parties. External relations may entail involvement in academia, the participation in conferences and professional events of interest. This does not only regard the technical application of digital design technologies, but also all conceptual levels, as well as the facilitation of double-loop organizational learning through the continuous reificative aspects of methodologies and tools at a formal level, but also through informal exchanges of ideas and experiences. The deployment of digital design methodology is supported by the operational strategies, and needs to regard issues of brokering, including communicating the operational strategies and techniques being employed to other members of associated design teams. Single-loop organizational learning is continuously facilitated through project based work through iterative development of digital and parametrical models, where important findings inform the continuous formation of the operational strategies.

Operational Digital Design Strategies

Operational design strategies formulated here are based on findings within the design projects included in the overall thesis, as well as the experiences of the author within practice. The design projects are discussed in terms of strategic definitions later in this chapter, the design processes have been revisited in relation to the proposed framework. This is also the basis for how the projects are presented in the Projects II book, but it is important to note that the projects were not necessarily originally conceived according to this framework.

In practice, these strategies are proposed to work as a framework that would need further specification when applied in a design project. Initially there may be little knowledge on what aspects of a project that may be relevant for digital design development, and the operational strategy may therefore require reformation during the process. The operational strategy should also be followed by a design narrative; an informal documentation that can provide direct feedback on actions taken in relation to the strategy, and provide long term documentation that adds information relevant for future cases of reuse of strategies, design tropes, tactics and methods. The proposed framework is presented in the following section, followed by the enquiry that explores how it can be applied to the design projects assembled in the Projects books.

The proposed framework includes different strategic levels that are applicable as the overall operational design strategy is formulated or formed for a particular project (either a unique strategy or the reuse of an existing strategy, which then needs to be adapted for the purposes of the specific project). The list has interdependencies; there are certain design tropes that are more likely to be affiliated with certain types of engagement, there are design tropes that are more likely to be affiliated with a specific parametric tactics, the types of design team participation can depend on the design trope and will also influence the parametric tactics employed, and certain parametric methods are more likely to be affiliated to a specific parametric tactic (although the parametric methods are the most likely to be of generic use).

A number of the levels can be regarded from the perspective of fragmentation; of processes, project aspects and digital methodology. Basic types of fragmentation are suggested, but must be specified for each project. Other levels depend on the ambitions and requirements of the project; such as resources and need for design trope development, necessary skill sets, activity systems and design patterns. The design narrative developed during the process, and supports knowledge management as well as the establishment and management of communities of practice.

1. Type of engagement
2. Project aspect
3. Design trope development or re-use
4. Design team configuration
5. Digital design tactics
6. Digital design patterns
7. Design narratives

Type of engagement

The type of engagement for the parametric endeavor may be multiple, but the initial point of engagement is an important one. This is not necessarily the same as the point of parametric application, but rather the point in which a discussion on parametric potential is initiated. Several types of engagement are possible within a specific project. These would preferably be facilitated in sequence or at least in dependence of each other, but

a project could also contain types that are not related (such as initial site analysis of climatic conditions, and a subsequent rationalization of structure).

Typical types of engagement include initial studies and analysis (such as solar and shading analysis of site conditions, programmatic analysis, infrastructural simulation etc), conceptual development (including forming a design concept that involves digital design potential, possibly integrated with the specific conditions of the project and/or in collaboration with other specialist fields such as environmental or structural engineering)[32], design evaluation (applying digital design techniques to evaluate design intent and conceptual designs, in order to provide proof of concept or to further develop and refine a concept)[33], design rationalization (such as the iterative refinement of a geometry in accordance to constraints such as fabrication limits or to aesthetic coherence), performance evaluation (such as the iterative refinement of a design in accordance to performance criteria such as structure, energy or light) and fabrication preparation (such as file-to-factory development of mass customized building parts or direct translation to BIM documentation).

The types of engagement are relevant for all lower levels of activity of an operational design strategy. In many cases these different types are strongly linked, which can suggest that more than one type is relevant.

Project aspect

The project aspect indicates relevant areas for the application of digital design work in the given project. This of course depends on the type of project and the areas involved, but may also depend on a strategic fragmentation[34] of the project into aspect that are more, or less relevant to explore by parametric means.

The applicable aspects include but are not limited to urban organization (the iterative design exploration of urban fields), infrastructure (traffic, pedestrian movement, sight lines, integration), landscape (formal variation, biotope differentiation), massing (formal variation, typology and contextual qualities), envelope[35] (the configuration of the envelope of the building in relation to massing, and the articulation of this envelope), spatial organization (the organization of interior spaces in relation to program and overall design concept) and interior partitions (the elements that delimit the internal spatial organization and how they are articulated).

Again, aspects are often associated to each other, and this relation may be an opportunity for parametric development in itself.

Design trope development or re-use

Digital design tropes are in particular relevant for formal design of building element, but can relate to all project aspects and to most types of engagement [Contexts II: p.41]. They need to be defined in order to achieve coherence in a project in relation to identity, programmatic principles, organizational logic and aesthetic ambition. They can seldom be set immediately; they are a result of the initial conceptual development of the project. They may also be differentiated across multiple strategic levels, and across scales of the project. The design trope may be a result of early digital design work, but an overarching trope could also be developed through other means, with specific digital design tropes that articulate or diversify the overarching theme. Potential design tropes can include specific variations of urban grids, massing principles such as stacking, Boolean operations or shearing, treatments of envelops such as folding, relaxation or component variation, principles for spatial organization through topological variation, hierarchical arrangements or fields of intensity, or articulation of interior partitions through transparency, aperture variation or color. They could also relate to more abstract processes such as types of rationalization, structural orders or responses to performance evaluation.

Design team configuration

Any digital design enterprise is highly dependent on its participants. This regards both technical prowess and conceptual ability to innovate, develop and implement design results. For advanced parametric development, the different skill sets of a team is of great importance, both within the project during development, and for long term follow up.

The competences of a team have an impact on the types of engagement (in regards to different types of performance evaluation, working understanding of praxis and design ability), the design tropes involved (many specific digital design tropes rely on specific skill sets in regards to both conceptual development and tools), the digital activity systems and the parametric patterns/methods (in particular in regards to technical platforms and understanding of specific parametric definitions within those platforms). It also has an influence on design narrative; not all designing architects and engineers have an understanding for the importance of documenting process and findings beyond the deliverables demanded of a project, and not all have ability to produce such documentation.

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30 See overview on Strategic Thinking, and: De Wit, Bob and Meyer, Ron, *Strategy: Process, Content, Context*, Thomson Learning, 3rd Edition, 2004, p.231–253

31 This proposal is partially based on the experiences from directing Dsearch, the digital design development environment within White Arkitekter AB, a practice with well developed strategies for IT and R&D. Dsearch is formally a part of the IT Methodology division, but also operates directly in design processes and has a strong affiliation to Kunskapsbygget, the internal R&D division of the same practice. When applied to a less formalized organization, it is still crucial that digital design strategies are aligned to other initiatives in regard to IT and organization development.

32 Comparable with the knowledge development strategy defined by Roland Hudson, although the approach to design problems is here regarded in a more open way [Contexts II: p.77].

33 Comparable with the knowledge capture strategy defined by Roland Hudson, although the approach to design problems is here regarded in a more open way [Contexts II: p.77].

34 Fragmentation may involve the division of problems and tasks as indicated by Hudson, but in this case it primarily involves the logical division of the project into aspects that to a certain extent can be treated individually [Contexts II: p.77].

35 See the presentation of Zaera-Polo's notion of the politics of the envelope in the Reformations chapter, where he defines typologies through envelopes, and indicates the political, programmatic and performative importance of the envelope.

The relation between specialists and non specialists is of particular concern for the digital activity systems and patterns/methods. If the parametric development is done by a pure specialist team on commission from an overall design team, the translation of design intent is crucial, as is the ability to communicate any restriction on the technical side to advanced design concepts. Since architectural innovation is facilitated in both, such as design team and in the digital design process, language may become an issue in order to align different trajectories of innovation.

If the digital design specialists develop parametric systems to be deployed and used by the general design team, great care must be taken to facilitate interfaces that are intuitive and easy to use. There is also a need to make sure that the design space / problem space covered by such tools are aligned with the needs and opportunities of the design task. Continued technical and user support is needed, as well as preparedness for restructure of the parametric system if needed. More advanced applications may also entail training for non-specialists, and documentation of applications.

If the digital design specialists work in a more integrated way in the general design team, it is easier to alter the parametric design system continuously. Care must be taken in how resources are distributed.

In all cases, the development process in relation to the overall design process must be planned and monitored. It is also important that the digital design development is not treated as black box development (opaque and not seen beyond the provided results). This applies to communication within the team, as well as communication with clients and other parties. While all participants need not understand the mechanism involved within parametric systems, they need to understand the requirements in regards to investment in time and resources, and how this affects important gates in the process (and hopefully also a positive change of quality in deliverables).

Design tactics

The Digital design tactics relates to the digital design environment within a practice in analogy of the strategic notion of activity systems, and involves plans for how digital and parametric principles can respond to the issues defined in the higher levels of the operational design strategy. This strategic level resembles the parametric design strategies proposed by Roland Hudson, but their objective is expanded. The task structure proposed by Hudson is primarily focused on the development and refinement of geometry in response to a given design intent, as well as the continued development towards construction documents. This field is expanded in two directions, and articulated in a way that includes additional types of tasks. It must encompass early stage development of conceptual design in those cases when digital design techniques are important drivers of such development. As recommended by Hudson, it also must cover the involvement of new fabrication, production and manufacturing technology as a potential asset, both in a way that can employ existing technologies for direct deployment, and as a way of experimenting parallel to the project development (this is necessary to prepare for future opportunities, and to push the development of producers in a direction that leads to such opportunities).[36] As indicated by Hudson, they need also to include the integration of performative evaluation (structure, energy, light, process) in at least two different modes; as light weight feedback within design software (that can be used by digital designers directly) and as communication with specialists external to the design and the digital developments teams.[37]

Furthermore, the digital design tactics cannot only depend on technical prowess; they must also contain support for and drivers of conceptual development. This entails an awareness within the teams, and a language to describe such conceptual development, as well as interaction and dissemination with communities external to a practice in order to discuss and evaluate findings in an expert context (beyond purely technically oriented environments). Such forums may include venues that drive the discourse of digital design development.[38] In addition, they need to address issues beyond the current spheres of interest of both technical and conceptual digital design. This may include politically inclined territories as such that are defined by the current notion of agency and the more progressive (and operational rather than representational) modes of sustainability, business oriented trajectories in which design has been identified as both a means for added commercial value and an opportunity to redeploy financial means to provide corporate social responsibility, as well as the discourse of architectural practice itself.

While the direct links to such alternate forums for the exchange lies at upper strategic levels of digital design, such issues must also be integrated into the tactical level in order to make them operative, and influence design decision made on a day to day basis.

A parametric tactic may also include initial ideas of what parametric patterns/methods are likely to be crucial for the design task, but during the actual design development such patterns may soon be replaced with other ones.

Digital design patterns

Digital design methods are assembled building blocks that enable iterative long term development over time through reuse. They may be developed within specific design project development in which they need to be encapsulated and generalized for re-deployment later, or they may be developed as isolated development projects independent of projects. Within a practice, they can be categorized and archived in repositories, in which case it is important that they include at least a minimum amount of documentation to allow reuse. Documentation is also crucial for future redevelopment of parametric methods.

Beyond the single practice, parametric methods have become widespread in online forums in which knowledge in parametric design is generated, evaluated, supported and disseminated.[39] They are often used as samples or tutorials to teach parametric design, as discussed by Robert Woodbury in his compilation of patterns for parametric design, based on the early development

of GenerativeComponents [Contexts II: p.24]. In this way, a number of archetypical patterns have been disseminated and reused to the extent that they virtually have come to represent design tropes. One of the most prevailing examples is the 'populate surface' pattern, which is a basic principle for the global distribution and local deformation of a component across a surface. [40]

Woodbury proposes a formal description of patterns according to the logics of What, When, Why, How, Samples and References, but also admits that a particular quality of the parametric design pattern is that they "provide concrete, working code as pattern instance."[41] While such documentation may be valuable for reference, such definitions are only beneficial for finding a pattern that is hopefully useful for a particular task. For the sake of continued development as well as adaptation of a pattern for a parametric tactic, the continuous annotation of the internal configuration of the pattern is more important. In a long term project such annotation is also crucial for the creator of the pattern; it is easy to forget how complex parametric definitions operate without having to retrace your steps or searching through it extensively. A well annotated pattern can easily be comprehended by other parties as long as it is archived with a short description.

The collection of patterns in a repository for internal use is beneficial for the sake of efficiency (it allows the designer to instantly reuse patterns that are frequently needed), but also as a process of documenting design decisions of significance. Sharing patterns beyond the borders of a practice is also important, in the sense that local development participates in a mode of open source that is beneficial to the complete discipline.

As the development of the technical platforms mode is fast, a crucial issue is the versioning of the parametric application itself. For professional use, as well as use in education, it is important to have consistency in how the application executes a parametric definition, and for longer projects the sudden upgrade may be catastrophic.[42] This also has an effect on repositories of patterns/methods, in that old definitions may be in-efficient, execute in an unsatisfactory way, or simply stop working. Version number should always be part of the documentation, and for advanced patterns a version of the application may need to be stored as well. Overall upgrading of parametric applications is a strategic decision, taken on a level above the operational strategy, but it is safe to say that upgrades should be avoided for all participants of a design team during project development, unless a new version provides substantial benefits.

Design narratives

While annotation of parametric definitions and documentation of patterns archived in repositories may provide a substantial part of the knowledge generated in parametric design, it cannot be comprehensive. Many of the more important findings take place outside the environment of the application, in relation to all other levels of the operational strategy. Parametric design is often suggested to be related to formalized design processes and provide an automated record of the design process, but the informal decisions and communications are far more elusive.

The design narratives are therefore crucial in the documentation of new design tropes, the evaluation of collaborative work, and in particular for the speculative aspects of the design conceptualization. During design development, there is little time to document anything beyond deliverables, binding decisions and time spent for invoicing purposes, so any such recording needs to be facilitated in a very intuitive way.

The higher strategic levels and activities within pure R&D environments have a strong agenda in reflection of current practice, for the sake of continuous learning and development, but this task is impossible without information on how a project commences.

Beyond the boundaries of an individual practice, such knowledge is also important for the development of the discipline as well as a general and specific discourse of practice. The early years of the digital design field in architecture saw a strong focus on process, even if those processes mainly included steps taken during the development of geometries, and that the purpose often was to brand an experimental practice through its methods. As focus has been somewhat realigned towards the end product, and its aesthetical and technical performance, there is a renewed need for more profound process documentation. This comprehensive strategy for digital design in practice proposes that the design narrative may be a good way to approximate such desires.

Design narratives are also a valuable in the development of design cultures, in the sense that they on one hand call for a more articulated and conscious mode of design that can be disseminated throughout a practice for a better understanding and shared ideologies.

Design narratives should be recorded as intuitively as possible (that may be compared to the common discipline of individual project diaries), but for the purposes of digital design development on a strategic level, they also need certain formality and alignment in order to be cross referenced. A number of concepts are interesting to record in design narratives. Events entailing

36 Hudson, Roland, *Strategies for parametric design in architecture: An application of practice led research*, PhD Thesis, University of Bath, 2010, p.255 Available here: http://opus.bath.ac.uk/20947/1/RHudsonEThesis.pdf (8/8 2011)

37 Ibid., p.110

38 While venues such as SmartGeometry and ACADIA are crucial for the continued development of the field, such expert forums could be expanded to address performance from an aesthetical, political, social and cultural approach.

39 Many such forums are independent or at least do not require any investment in software to access. The GenerativeUser Forum, facilitated by Jalal El-Ali from 2003 – 2008 was crucial in the early development of Bentley's parametric application. Today the Grasshopper forum has a similar role in the development of this parametric plug-in to McNeel's Rhinoceros modeler. http://www.grasshopper3d.com (12/8 2011)

40 This is referred to as 'Jig' by Woodbury, as 'design surface' by Hudson and as 'framework surface' in Projects II. Other examples include proximity deformers that use a proxy object to feed differentiated values to a matrix of objects.

41 Woodbury, Robert, *Elements of Parametric Design*, Routledge, 2010, p.188

42 In the past year (August 2010 – August 2011) Grasshopper (which is in beta stage) was updated 23 times, with the latest update v. 0.8.0050 breaking forwards compability. http://www.grasshopper3d.com/page/next-build (12/8 2011)

any expected or unexpected event, such as changing programmatic conditions, new technical advances made available during the run of the project, or new discoveries made due to the exchange of knowledge between different parties. Actions include important design decisions, but also the discarding of ideas or proposals after evaluation. Arguments include the reason behind decisions, but also the objectives for conceptual development.

They may also be divided into different perspectives; a comprehensive design narrative may include an in-depth critical evaluation which remains private to the practice for internal reflection and future reference, and a simplified (but correct and coherent) perspective that can be used for external communication.

There are relevant examples in the extensive publication of processes that have been published by key practices over the past 15 years, but these must be treated as part documentation, part discourse employing selected experiences, and part branding and marketing. The main interesting aspect of such publications may be the way they are organized; they are often based on a post-rationalization and sometimes even a post-manifestation mode of writing, which could be valuable from the strategic perspective of R&D in conjunction with the operational design strategies. The narratives should also make use of the multiple modes or representation already being produced in the design development (including discarded material and early conceptual sketches), and may involve the parametric definitions themselves.

Operational Digital Design Strategies — Applications

This section investigates the strategic potential in the design projects included in the two Projects books of the thesis. None of the projects were designed using the proposed system of strategies, but the inquiry made here explores certain aspects of, primarily, the operational strategic levels as applicable for each case. The context differs between the projects; they include design projects developed as independent experimental endeavors, student projects in which the author set the conditions and functioned as a tutor, and examples from practice within the Dsearch digital design environment. For all projects presented in the Projects II book, the discussion on strategies in this section is formalized as part of the project documentation as referenced in each section. The Krets projects presented in the previous Projects I book instead include a basic overview over potential operational strategies identified.

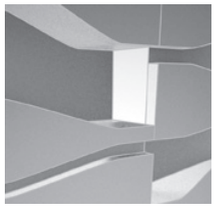
Design Projects Enquiries

The projects presented in the Projects I book of the licentiate thesis do not include the descriptions of the operational strategy levels since it was published prior to the development of these strategies, but they can still be assessed in a similar way to the projects in the Projects II section. Most of the projects were developed in the Krets research group, and were not subject to the contextual qualities of the student projects, nor the relation to the issues of practice as present in the Dsearch projects. The two projects PARCEL and SplineGraft do however form contexts for the series of prototypes that were employed during the design development. As presented in the licentiate thesis, the projects are already fragmented according to the concept of design loops [Projects I: p.07], and this overview will also suggest a relation between design loops and the introduced strategic levels.

While the student projects included in the Projects II section were developed in a guided way and as response to a given conceptual and technical framework, they are also results of innovation driven processes in the way each student has found his or her way to respond to a given assignment, and in the way the overall process has unfolded accordingly. In respect to operational strategies, the projects were not initiated with specific strategies in mind. Several design decision were made with an intuitive approach, and as the complexity of the projects were built up, new decisions on how to move forward had to be made. In a student project there are also few opportunities to formulate strategies as a basis for collaborative decisions, but through series of tutorials, reviews and presentations as well as interaction with external parties such as the technical studies tutors, the design methods developed could still be seen as strategic assets. All through the process, the purpose of each method needed to be formulated, and the need to switch media or to use alternate techniques was frequently discussed. The documentation of these strategic moves was primarily graphical and aural, and they were not clearly isolated or defined separately. They can still be identified, even though it takes an understanding of the process as it progressed as well as the documentation available in the portfolio from which all representations in Project II were extracted.

The digital design development within Dsearch is primarily directed towards specific projects within White Arkitekter, but they also entail conceptual additions to existing ideas of each project. They originate from opportunities provided from within the scope of a project, and through these opportunities they add value to the project. In most cases they have been initiated external to the project budget and timeline, providing a pocket of innovation that is not dependent on the restrictions set at the start of the project, but in order to be implemented they need to be strategic in the sense of defining and limiting the type of engagement and the project aspects involved, as well as taking the design team configuration into consideration. These set the conditions for design re-use or design trope development, and the design tactics and parametric methods employed. In the case of team collaboration, development could either be done by specialists only or the parametric model could be prepared for direct interaction by team members with limited specialist skill sets. As the parametric design development becomes integrated into the overall project development, modes of communication and documentation must be considered, for internal team evaluation and for project documentation delivery. During the early development of Dsearch, an important ambition was to expand the territory of digital design applications within White Arkitekter AB. One instrument for this was a series of presentations based on external references that illustrated potential project aspects that could benefit from the introduction of digital design workflows.[43] The following design projects enquiry discusses the projects pre-

sented in the thesis, as well as cases from the licentiate thesis, from a strategic standpoint according to the previous discussed criteria. Each project is also documented in terms of the strategic levels introduced previously, in the Projects II section, [Projects II: p.170]. The 'design narrative' level of each project is presented as part of the overall project documentation in the same section [Projects II: p.94].

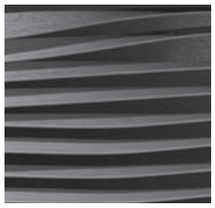


The '**PARCEL**' project was initiated on the interest in certain material behaviors and fabrication principles [Projects I: p.10]. The innovation driven approach in which the project was formed and reformed through iterations did not allow an initial strategic approach, on the contrary the design approach was in opposition to this [Contexts I: p.45]. Six different design loops are presented in the project documentation, representing the formal development, the recombinatorial potential (which is closely affiliated to the formal principles), the aesthetic performance of the electronic network (integrated in the folded structure), the production principles (again based on the principles of folding), the architectural performance and the refinement of the form through parametric modeling. Eight modes of prototyping were presented in the documentation, in addition to the prototypical properties of the final physical assembly [Projects I: p.12].

If the PARCEL project is considered in its completeness, it could be regarded as a response to a comprehensive engagement from its initial studies through design evaluations, performance evaluation and fabrication preparation. While it was developed as a standalone installation, it was proposed as an interior wall paneling system that could be part of a larger project. The formal principles that were at a later stage redeveloped as parametric system could be regarded as design trope signified by the unique architectural qualities based on folding principles and the structural behavior of curved fold lines. The parametric model required customized development, and could be regarded as a parametric pattern in regards to the dual control of representational model and fabrication templates. The documentation of the process through text and representations constituted an extensive design narrative, fragmented into design loops.

In the project development, the series of prototypes were not intentionally fragmented; this partitioning of the project was instead conducted through the design loops. The integrated character of the PARCEL projects does not easily make these design loops re-deployable fully in other contexts, they rely too closely on each other. These relations are hierarchical and propagate from the formal folding principle. If regarded as abstract principles for operational strategies, this suggests a series of strategic engagements that depend on each other in a linear way, which may be regarded as limiting, but also provides integrated designs with multiple performances.

The types of engagement in the PARCEL project in regards to digital design methods included direct modeling for form, recombination and folding principles, simulation of network behaviors, preparation for fabrication, the programmed reactive behavior and the redevelopment through parametric modeling. The project aspect involved the articulation of interior surfacing. The new design trope developed through physical folding and digital modeling gave integral structure adequate for the scale and is refined in the parametric solutions space and fabrication design loop [Projects I: p.36]. The design team consisted of three Krets members, one of which had programming skills for the reactive behavior. The activity systems included digital models that mimic folding principles explored through physical modeling and investigate recombinatorial potential, digital simulation of network behavior through Processing, development of fabrication templates for die cutting, the printed network and coloration as well as the parametric redevelopment that introduces a solution space for form variation linked to production instructions. The parametric redevelopment also introduced the dual representational model and fabrication template as a parametric pattern. The extensive design narrative is available in the Projects I book [Projects I: pp.10-53].



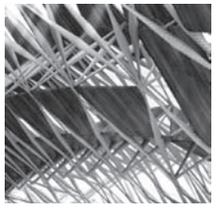
The '**SplineGraft**' project started with an interest in the potential of kinetic actuators as means to dynamically articulate an interior wall paneling system [Projects I: p.54]. The initially set programmatic conditions for the project still provided a number of challenges in its design development. The formal principle of the transformable spline early on set conditions for panel material, the choice of which required a structural system for primary support. The project documentation presents three design loops, fragmented into the structural system, the performance of the panel (including geometry and material performance) and a parametrically modeled refinement of the structural rack. Nine modes of prototyping were employed through the process [Projects I: p.56].

Considered as an overall project, SplineGraft shared many of the principles from PARCEL, including the range of engagements and the concept of the interior paneling system. The formal principle of the panel was directly influencing the kinetic performance, and as such could be regarded as design trope characterized by the combination of geometrical properties, material performance and kinetic behavior. The structural rack and the panel were not co-dependent beyond the connected actuating mechanisms and the potential of the racks to reset the overall shape of the panel. The integrated electrical network combined with the reconfigurable racks could be regarded as a second design trope, through the geometrical principles that allowed electrical connectivity and structural stability in all configurations as well as the aesthetic qualities that emerge from this. The further parametric development in the SplineGraft Refit design loop diverged from these principles, and was only developed in regards to form and structure, and was thereby not following this design trope [Projects I: p.80].

43 This was initiated in the fall of 2010 as the author became the director of Dsearch, the digital design development environment within White Arkitekter AB. The term 'digital design strategies' was employed to indicate what parts of an architectural project that could be relevant, in the context of this thesis a more accurate term would be project aspects.

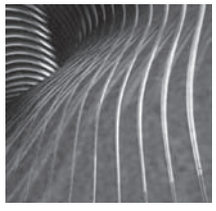
The fragmentation between panel and structural rack was deliberately planned, and could also be seen as different project aspects. The actuating mechanics in the structural rack were designed to carry a panel, but could be applied to alternate designs. Likewise, as shown in the SplineGraft Refit design loop, alternate structural frameworks could be used to carry the panel with similar or improved results. In analogy to the PARCEL project, SplineGraft suggested strategic engagements that are related, but in this case they could also be deployed independently.

In SplineGraft the types of engagement in regards to digital methods included direct and parametric modeling to simulate formal kinetic performance of panels, iterative modeling of the structural rack components, simulation and programming of reactive behavior of the kinetic performance and the redevelopment of the structural rack through parametric modeling. Again, the project aspect involved the articulation of interior surfacing. The two new design tropes regarded panel form and performance as well as the component based structural rack with integrated control circuitry that also provided aesthetic qualities. The design team consisted of Krets members, one of which had programming skills for the reactive behavior. The activity systems included an assortment of digital modeling approaches for formal simulation, structural rack modeling and fabrication preparation, digital simulation of kinetic performance through Processing, and the parametric redevelopment of the structural rack involving propagation in two dimensions with customized components producible through cnc-milling in combination with folding. The parametric modeling involved follow very general principles and does not provide re-usable design patterns. The extensive design narrative is available in the Projects I book [Projects I: p.54-85].



With a main objective of developing adaptive structures with architectural potential, the '**Flexible Space Frame**' project was initiated in the exploration of material composites, and how a composite behavior enabled structural capacity with integrated adaptive performance [Projects II: p.96]. The development process for the project was rigorous, and while it related to the given phasing of the unit, the student also built up a strategic plan based on a step-by-step exploration of the potential of more advanced versions of the initial material studies. The approach of the project required continuous interaction between physical and digital development, and most strategic levels included both. When broken down, four main types of engagement can be defined for the project; adaptive behavior, geometries and mechanisms, fabrication and architectural performance. The project aspects operated at several levels, including structure, massing, envelope, spatial organization and urban organization. The core of the project can be identified as a new design trope; the adaptive structure, which was continuously re-interpreted throughout the processes of development. As all AA student projects, it was carried out individually, but with internal support of unit tutors and technical advisors. In addition Skorick involved external specialists in new materials, digital fabrication and environmental design. A number of design tactics were formed during the process, including analytical exploration of material performance, analytical evaluation of generative digital models, physical mock-ups and reference studies and evaluation through design implementation. The scripted behavior of geometrical transformations became a re-usable parametric method throughout the project. The design narrative tells the story of project development, and relates the various design tactics. As the mode of operation of the unit was portfolio based, the project is primarily documented through a series of 58 panels, with photographed physical models and drawings / renderings based on digital models, but also analytical material such as references from the initial material studies and in-depth site analysis.

The Flexible Space Frame project could be regarded as employing a number of design strategies of different hierarchical relevance, where a lower one (a material performance strategy) could provide important input to a higher one (an adaptive structure strategy). These strategies are all intertwined, and while the flow of information was not automated but rather mediated through the frequent use of abstractions and drawings that allowed a deeper understanding of particular project aspects and engagements, it is for the purposes of this thesis more interesting to define an overarching and comprehensive strategy that combines the different design explorations, here defined as design tactics.



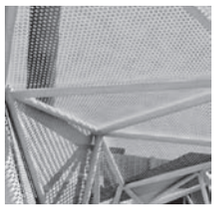
The '**Slumbering Space**' project was developed fast track, in response to the requirements of the primer set of three workshops starting up studio 11 [Projects II: p.108]. The workshop briefs asked for design development in three stages, with a starting condition of two vertically associated spaces of different character. Stage 1 entailed the formal design of the interiors of these spaces through shaping (continuous shifting spaces) or composing (through the composition of a set of objects). Stage 2 asked for structural systems that would support the spaces physically and conceptually. In stage 3 the students were required to consider the exterior and ground conditions. The Slumbering Space project employed the assignment through the mode of shaping, and the idea of continuity prevails also in the design process. When fragmented, this project primarily engages in spatial generation, design rationalization and implicit (the evaluation of spatial qualities through renderings) and explicit (the direct feedback from structural evaluation software) performance evaluation. As basis for these engagements, the project aspects involved, include massing/spatial studies and envelope development. The relative simplicity of the project gives it clarity, and the final design proposal could be seen as a design trope in itself, or as an integrative digital design strategy for the refinement of a self supported spatial envelope. The project was developed individually, with the support of tutors in regards to design, digital techniques and structural evaluation.

The overall project may be seen primarily as a study of the integrative uses of certain digital design tactics, but as such it also suggests simple and straight forward relations between design model and evaluation principles, with a potential for bi-direc-

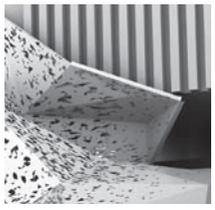
tional feedback. As such, it can be regarded as a design trope and an advanced parametric pattern, on which a more advanced comprehensive strategy could be formed.

The '**Labyrinth Wall Pavilion**' project was also developed as part of the primer set of three workshops in Studio 11, following the shaping approach [Projects II: p.114]. The overall spatial form and organization was set up very early in the design as two cubical spaces oriented vertically against each other, and was not updated throughout the process (at one stage a more organic approach was considered, only to be immediately abandoned). Articulation was instead instigated through a component based approach, in which simple orthogonal panels were randomly distributed in several layers. The parametric requirements of the complex association of simple parts were advanced from stage one, which in effect broke the pedagogical idea of step by step development from simpler models to more advanced systems. This was also present in the physical organization of the designed system, through the way that architectural articulation (layering and apertures), structural integrity and vertical communication were all produced by the singular system. While the initial spatial conditions remained, the system gradually disintegrated the rigidness of these spaces through layering, blurring the borders between interior and exterior as well as upper and lower level.

The adherence of the initial concept and the rigor of development allowed basic programmatic features such as the entrance and the vertical communication to be integrated into the system. Beyond the directed random generation and distribution of panels according to the intended gradual perforation of the fragmented walls, the structural properties set requirements for connecting units that were also evaluated in terms of visibility (they were meant to be hidden between the main panels). Basic structural analysis of deflection was conducted on key sections, which informed the allocation of the connecting units. In essence, the project aims at the development of one aspect; the self supported, layered and perforated wall, with complementary additions for communication and stability that do not conflict with the formal concept. As such, the project as a whole could be regarded as a design trope with a supporting digital design pattern in the form of the parametric system. In extension, the project could also be regarded as purely a system that could be programmed according to preference, to be adapted to any spatial organization based on orthogonal partitions. While the different basic programmatic concerns could be fragmented, the design process, the parametric model and generated formal outcome could not.

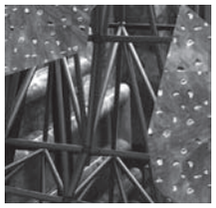


The '**Mix / Share / Invite**' project was also a response to the assignment to design a visitor centre to the existing power plant in Högdalen [Projects II: p.120]. The distribution of the different parts of the center was based on an understanding of the development of the overall facility over time, which set the conditions for programmatic aspects such as passageways and the location and massing of the main center. The main center, formed as an abstraction of the topography of the landscape with extractions to provide light to the inner parts, and the passageway providing access to key locations of the power plant, use a similar formal approach. Then main digital development was targeting the passageway with the ambition of enabling long span freestanding structures supported by a geodesic tube. The development of this tube could be considered a design trope re-use, with the basic premise of a triangulated structure that was refined for structural optimum. In locations with additional support from the existing structure of the facility, the space of the tube could be expanded to incorporate additional programs such as a lecture space and vertical communication. The formal principle of triangulation was also re-used for the main building, through the tilted main steel structure and triangulated cladding principle. There is a formal resemblance between the two main parts of the project, the methods used differ. The geometry of the tube was explored through parametric modeling with structural analysis feedback, while the geometry of the main centre was developed through direct modeling following structural principles rather than evaluative feedback. Further fragmentation could be designated between structure and paneling in both cases.



In the '**Adjust(ed) Folding**' project the team of students was faced with an existing industrial facility as site [Projects II: p.126]. Continuously developed during a period of 30 years due to increasing demands of waste processing and energy production, the initial architecturally legible components currently communicates an architecture of function only. In the task of designing a small addition that would transform the identity of the facility, their formal approach was to partly wrap the existing structures and include new program in the folds that would be created.

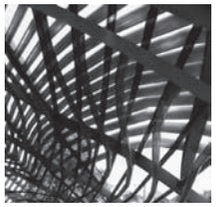
The overall formal approach, a design trope in itself, enabled the design team to develop a geometrical principle that would be applicable to all parts of the project, which in turn allowed the parametric design tactics tested in individual parts to be regarded as cases for an overall global development (which was beyond the scope of the design task). Beyond the overall formal design principle of crumbled/ formal pattern, the deployed tactics involved feedback on daylight effect on design alternatives in two different ways. The triangulated surfaces were iteratively re-con-figured to explore how overhangs would shade floor areas [Projects II: p.129 > img.10], and apertures in the triangulated elements could be controlled in regards to size and number in order to explore how interior spaces would receive daylight [Projects II: p.129 > img.08, p.130 > img.13–15]. Both approaches are also related to the internal structure of the main elements, which were designed as sandwich elements.



The '**Amongst the Machines**' project was developed in response to the given brief of designing a bio fuel combined heat and power plant with associated program, and was according to the course schedule developed in three stages over two semesters [Projects II: p.132]. During the first semester, an overall schematic design was developed, including programmatic development (and identifying the public program as primarily a climbing center), site use, overall massing and formal concepts. The second semester was initiated by a three week workshop, in which the students had the opportunity to conduct in-depth studies of project aspects of their choice, to be integrated into the overall project which was further refined for the remained of the semester.

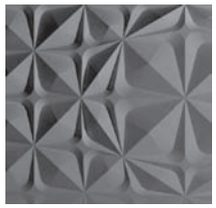
This fragmentation of the design process allowed students to formulate informal strategies for their in-depth study, and in the case of this project this entailed parametric studies on triangulation patterns in general, and the space frames combined with surface paneling in particular. This decision was presented and discussed as part of the interim reviews at the end of the first semester. The choice of triangulation principle can be regarded as the re-use of a design trope; even though this is limited to a patterning effect and a basic space frame configuration, the re-occurring theme in different project aspects provides a unifying formal concept to the project. This formal approach, while investigated as a space frame during the in-depth workshop, was pursued through different parametric principles throughout the project, with the terrain aspect being the second most developed.

The overall project can be seen as a framework in which the re-occurring formal theme performs different tasks. The treatment of the ground gives a base to the facility, provides usable surfaces for occupancy, and articulates the entrance situation. The corresponding façade deployment comes in two versions; the cladding of the boiler house and the excavation of the bunker envelope, providing architectural identity and principles for apertures. The space frame linking the two structures also operates as a physical frame work for the climbing centre and the triangular geometry of the frames are used for the formal principle of the climbing panels.



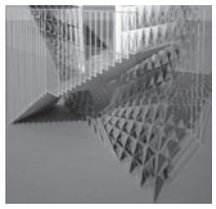
The '**Subversive Resilience**' project was developed as a diploma thesis project within studio 11, and partly followed the scheduling of two semesters and the in-depth workshop [Projects II: p.138]. The student added specificity to the program in terms of the photobioreactor, but followed the studio agenda of adding an additional public program. The basis for the project was the thesis booklet, a compulsory document as preparation for thesis work and part of the KTH curriculum. This document set the initial conditions for the project, and the overarching objectives that refer to using environmental techniques and technologies to be used as programmatic premise, and the specific use of photobioreactors as architectural features that brings value to the context as well as the facility itself. Beyond the background research this document regards digital design as providing tools to support design processes with iterative feedback, through parametric modeling enabling model modification, analysis software to evaluate daylight and structure with feedback to the design model, and the use of rapid prototyping technologies.

The use of digital methodologies beyond the initial daylight studies was subordinated the overall design process, with a series of key developments that influenced this process. The massing and envelope scheme was developed as direct modeling in combination with parametric modeling, in order to define general catenary cross section, the diagrid structural system and the distribution of tubes for algae growth. The combination of catenary sections with changing dimensions that provides overall massing and the diagrid structure that is deflected depending on structural analysis establish a particular design trope. The associated digital models used for development were then to be refined through direct modeling, for local definition such as the intersections of the main structure performing as partition or open access.



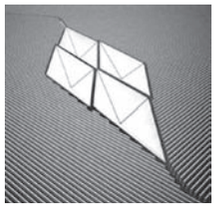
The '**Koggen Ornament**' project was developed very late in the design process for the overall building project, in response to an opportunity for further refinement of façade patterns, identified by the project team [Projects II: p.146]. The formal concept was based on initial references of relief patterns, and the objective was to develop a project specific pattern, along with a system to allow a non specialist to further manipulate its configuration. The first stage of development included both an angular approach to the pattern, and a smoother softer shape, in which corners were filleted. The softened shape was abandoned in favor of the angular after discussions with the design team, but the parametric features could be re-applied at a later stage.

The study was never implemented due to a re-consideration on behalf of the concrete producer, in which a rubber matrix was claimed to be necessary, which in turn would have required an additional step in the mould preparation (cnc-milling a timber positive cast rather than a negative one, and the in between negative cast of rubber – one for each specific pattern).



The '**Reframe**' project was developed as a generic system with specific qualities in regards to the partition components; they were triangulated and stepped, and through their geometrical configuration allowed variable light control, and a fabrication logic to enable a simplified assembly process [Projects II: p.152]. The first implementation regarded a project specific stairwell with an integrated partition for light control. The parallel development allowed exploration of the system unhindered of project timeframe, and while the specific situation of the competition entry was used as a basis for development, the system could easily be adopted to alternate situations. The particular design of the components could be considered a digital design trope, that

combines the triangulated panels as compression members, and the cable network as tension members for structural integrity.



In the '**Quality Globe Hotel**' project, the starting point was an overall design theme that was used in a mood board fashion to direct the design of exteriors, public interiors as well as hotel rooms [Projects II: p.158]. With the particular focus on the cladding of the conference room extruding into the open foyer, there was already a rudimentary formal derivate from the overall formal concept [8], but the design team had already considered this more of a place holder for a more advanced design. With the mood board and the initial formal concept as a basis, a short and intense workshop could quickly form a concept, in which the awareness of the potentials and limits of a parametric system provided enough insight to set up an initial parametric model. An important criteria was also the fact that two design team members had some knowledge of parametric modeling, which suggested the development of a generic system (controlling lamellas and diamond components) that could be directly controlled by geometries in the model (the control lines) as well as changing parameters in the parametric Grasshopper model. With a basic parametric model in place, the most advanced task was instead the geometrical development of the framework surface, and how different regions of lamellas would relate to each other as well as the global form [Projects II: p.162 > img.14–16]. This direct modeling exercise proved to be particular to the established design trope, in the sense that the way in which different lamella regions could relate to each other would set up the conditions for how many systems would be needed, and how the borders of the regions would be defined. The overall parametric development could in this sense be seen as generic, but the basic form of the framework surface had great influence on how the regions needed to be defined. While the envelope of the conference room to be designed was partly covered by other structures, all corners were exposed, and the overall form therefore needed to be addresses. If the system would be deployed on a single wall, or on a partial envelope, more basic principles could have been used, as presented in the early studies [Projects II: p.160 > img.10–13].

Summary:

In the Strategic Implementations chapter, strategic approaches to the implementation of digital design are investigated through a review of key concepts in strategic management and studies of learning organizations. In parallel, the reference of parametric design strategies proposes a number of strategies for cases in which the objective for digital design is relatively clear and concise, and this reference also suggests the relevance and importance of strategic thinking in situations that are less well defined. On this basis, the idea of comprehensive digital design strategies, expands the territory explored by Hudson to include organizational development, but also delimitates the territory explored in this thesis to early design stage development. The strategic levels of the proposed framework serve to identify a wide range of possible project engagements, and suggest that digital design endeavors must be integrated in overall design workflows. The design process also requires openness, and the inclusion of a speculative approach, in order to remain vital and creative, as in the case of new digital design trope and digital design pattern developments. Strategic frameworks must be developed over time, and the different levels of the operational strategies presented here may only be a starting point for a prototypical approach to digital design strategies.

¬ Fully open ended innovative approaches as employed in experimental design projects may not allow for initially defined operative strategies, but once development is underway, the formulation of such during the process can direct the subsequent design steps.

¬ The notion of design loops can be used as strategic instruments to fragment the design process and analyze the relation between different partitions, which may suggest strong relations and co-dependance in an hierarchical way, or loose relations in which certain aspects operate as interfaces. This is relevant for process planning, in which design development may have to be conducted in succession, or in parallel.

¬ A single project, even at a small scale, could involve several design tropes that may require that the association between them is loose with clear interfacing features.

¬ Design tropes associated with digital design patterns may be developed as studies within an open environment such as the educational studio. Even if not all associations between different elements are fully functional, such a study may indicate potentials for further development.

¬ A design trope may respond to contextual and programmatic concerns, and create a framework for performative studies as well as fabrication principles.

¬ Integrated parametric models that include structural as well as formal aspects could follow different logics that set conditions for their configuration, such as the shape versus the composing approach suggested in the Studio 11 brief.

¬ More complex projects benefit from shifting design modes between physical and digital modeling, and digital design principles may first be explored through conceptual development as part of the overall design process, to be later fully developed and deployed as part of the project. This depends on the possibility to fragment the design tasks within the project, and the possibility to control the phasing of the design process.

Reflections

> *"The post-Albertian architecture of our digital future will have something in common with the pre-Albretian architecture of our artisanal past, but this does not mean that digital architecture might or should look Gothic — nor any other style. For one think, premechanical classicism was as much parametric and generative as medieval stereotomy. But this is not the point. Similar processes do not necessarily beget similar shapes. Understanding these processes, on contrary, will help us shape better things."*

Mario Carpo, '*The Alphabet and the Algorithm*,' 2011[1]

Synergies and Oppositions: A Prototypical Approach to Design Research

My starting point for this doctoral project began in the notion of the prototype. Previous experience in experimental practice, and in conventional practice, contributed to this approach, in the general preference of something open to reinterpretation and continuous development over designs regarded as final. This inclination led me to an interest in many things, but only aspects of those things, a mode of exploration that entitled myself to be fascinated by projects, processes and practices that may not have been the most recognized among my peers.

The two new research areas I propose in this thesis were defined after the realization that it would be virtually impossible to introduce "new knowledge", at least a kind of knowledge I found relevant enough, purely from within the realm of digital design, in combination with a slight frustration over the "given issues" of the field; the shift towards fabrication, the emphasis on formal innovation and the continued debate on how parametric software provides most potential. I believe that there is still a potentiality within the digital field, there are opportunities waiting to be explored, and my ambition is that a speculative mode of working still can involve relevant issues external to the design process. I also believe that there lies great potential in the intersection between an experimental mode of practice, and the knowledge that exists within the architectural discipline in general, as well as within other disciplines involved in the creation of architecture.

My initial ambition for the doctoral thesis was also dual; to explore the potential of design as method for research, and to do research on design processes. Later this was re-evaluated, and focus was put on exploration and definitions of design methods in relation to the idea of the prototype, and bringing a research oriented approach into practice. This also included considering what research in relation to digital design could entail, which in my mind must mean something beyond a rigorously developed design project. Observations of both process and design outcome was deemed important.

If this thesis cannot claim to provide generic design methods for the purposes of conducting research, there is certainly design in my mode of doing research. The thesis as an entity, including the text and the assembled project documentation, is indeed a result of a design process. This has to some extent required a double agenda. To suggest that speculative modes of design can be related to speculative fiction, and that strategic thinking could be relevant for the digital design field, was in itself a speculation, which required the design of the research process. In parallel, my engagement in teaching and practice and the opportunities that arose during the progress of the doctoral project, while being carefully considered before accepting, required double agendas as well. Teaching students while monitoring their work for research purposes required facilitating a mutual benefit; the provision of a learning environment as well as the enforcement of methodologies and approaches relevant to my research was essential. My involvement in practice was subject to similar issues, with the willingness and interest shown by my superiors as well as colleagues in the two different practices I have been part of during the research process.

My final ambition with the completed thesis is to establish the two new areas as relevant ways forward for future research and practice within the digital design field. The speculative approach as a future field of research would benefit from being formally introduced as part of course curriculums and concepts used in practice. The more intrinsic relations between the ever evolving digital design field and a speculative mode of practice could be defined, and the implementation could be further supported through a deeper understanding of historical precedence; those introduced in this thesis as well as others. The strategic principles introduced in the thesis likewise requires "field testing," while they have been formed as a result from experiences in practice and education, there has not been opportunity to fully implement the final proposed frameworks. In both these scenarios, a continued use of a prototypical approach would be em-

ployed; initial frameworks would need to be continuously adapted and evaluated.

The two new areas could be seen as two opposites; a speculative mode could be assumed to require very informal and open ended processes, and a strategic approach may be expected to require very formal and well known design methodologies and well defined tasks. The innovative approaches that were vital for the development of the Krets projects presented in the licentiate thesis entailed a step by step reconsideration of methods employed and design objectives, even though the completed projects as documented lends themselves to a post-process classification of strategic issues. A student cannot be required to understand the strategic steps of a design process he or she has never before utilized, in particular when asked to also develop innovative design proposals that are relevant beyond the disciplinary discourse. Still, there are tendencies observed that points in the other direction. Extrapolation as a method for design depends on an understanding of the issues serving as a basis for the extrapolation, and a framework that serves as a basis for formatting and disseminating knowledge gained can allow the designer to focus on the design at hand.

Furthermore, the different approaches in the discourses presented in the Reformations chapter may sometimes oppose each other, or even employing similar terminology with very different connotation, but to me, the potential here lies in synergy. There is relevance for an aesthetic discourse; it is essential for the understanding of values generated in formal and spatial design, and important for the development of precedence. The foremost danger of becoming a specialist is that general discussions of architecture may be disregarded in favor of problems present within a certain methodological field, and this is certainly the case within digital design. This should not prohibit a specialist to involve herself or himself with those issues, but the often assumed traits of the architect; to be able to synthesize knowledge from many different fields is as relevant within digital design culture as in other aspects of the discipline. The definition of specific conditions and resources within the digital design field and their applicability to "problems" of general nature is essential, both to inform the internal development and discourse, and to bring findings into other contexts.

Treatises, Manuals, Discourses

During the completion of the licentiate thesis in 2008, the relation between design projects and what I decided to define as contexts (as opposed to methodology, theory or discourse) provided a challenge. This was resolved by never merging the two, but rather creating a loosely associated network of links. In time, I realized that while there was a lot of potential in that format, there were also several lost opportunities. In the work with this doctoral thesis, a similar starting point was chosen. But as opposed to the previous phase of the doctoral project, I initiated a process of slowly attaching the two, which I believe brings a propositional character to the work beyond the design qualities the discussions on key reference and the introduction of two new trajectories. I would like to see the work presented here as the last version of a series of prototypes, initially outlined as a sketch briefly presenting the different components of the thesis, with conclusions emerging successively through the iterative processing of design projects exposed to concepts borrowed from strategic management and science fiction studies. In many ways I have been operating as a designer in the making of the thesis, and as with any design project, it has at times been a constant shift between an overall view, and in-depth studies of particular areas. In this way the thesis has been constructed along side with the formation of the new proposed research areas, the study of sources on the discourses of digital design in architecture, science fiction studies and strategic management.

Future Research

As discussed previously, propose that there is an on-going reformation of the digital design field in terms of discourse and mode of practice. Certain trajectories can be seen to distance themselves from the origins in digital design techniques and methods, through aesthetic discourses, or issues of material performance.[2] This expansion of the field is important, but as suggested before there may be a risk of unnecessary dichotomies, of pure technical focus, and of a dismissal of the relevance to further discuss how digital design techniques influence design processes, and in extension design outcome. In parallel, scholars from other fields have shown a newborn interest in the issues at the core of the field.[3] This may indicate an understanding of the potential of digital design methodologies in relation to wider architectural issues, and recognition that the development within digital design is not disruptive in the sense of breaking the linage of architectural history. The current reformation within the digital design field has also been signified by redefinitions of geometrical approaches, and explicitly manifested as a style.[4]

I believe that these tendencies are natural extensions to previous experiments, in that they seek new territories to explore. This is not to say that these actors previously shared identical notions of the field, or that they are necessarily opposing each other. What can be discussed though is whether they expand a field of exploration and still share a common ground, or if they should be regarded as completely different endeavors. This is to question if there is a common field of digital design, and if common design techniques are enough to define such a field. With the research work in hindsight, I would of course argue that this field is a rele-

1 Carpo, Mario, *The Alphabet and the Algorithm*, The MIT Press, 2011, p. 128

2 As exemplified through: Sotamaa, Kivi, 'Frozen Void: The Elegant Affect of the Evolved Object,' in: *Architectural Design: Elegance*, vol. 77, issue 1, Wiley, 2007 and DeLanda, Manuel, 'Material Elegance,' Architectural Design: Elegance, vol. 77, issue 1, Wiley, 2007

3 As exemplified through: Carpo, Mario, *The Alphabet and the Algorithm*, The MIT Press, 2011, and Picon, Antoine, *Digital Culture in Architecture: An Introduction for the Design professions*, Birkhäuser, 2010

4 As exemplified through: Burry, Jane & Burry, Mark, *The New Mathematics of Architecture*, Thames & Hudson, 2010
Schumacher, Patrik, 'Patrik Schumacher on parametricism – "Let the style wars begin",' in: *The Architects' Journal*, May 2010 http://www.architectsjournal.co.uk/critics/patrik-schumacher-on-parametricism-let-the-style-wars-begin/5217211.article (2/1 2011)

vant notion, regardless if it is seen as a construct or not. There is potential mutual benefit between the different approaches presented in this thesis, and even if defined differently, a common framework is relevant to enable this.

The contributions I have offered to this reformation of the field, as part of the thesis, may be regarded as operating through different modes, and with different objectives. They have been proposed as frameworks in themselves, rather than discourses or methodologies, and with in mind, they are meant to be expanded upon, and explored further. The notion of speculative approaches, and frameworks, was initially formed through my belief that there still are potentials that are missed, as the digital design field moves towards a deepened interest in issues of fabrication, and even 'usability'. With this starting point, I explored the field of science fiction studies, in order to find underlying conditions identified by others. As I conducted design projects enquiries from a speculative perspective, I realized that speculation is inherent to the design field, but that there may be value in acknowledging this. Furthermore, my distinction between speculative process, discourse and practice also suggests that a speculative approach within daily design practice may have an effect on the discipline at large, through the establishment of a discourse. The recognition of science fiction as a valuable asset has been given within a wider design field, and 'design fiction,' as proposed by Julian Bleeker and supported by Bruce Sterling, has been suggested to found "a new engagement in 'prototyping' conjectural projections of designed futures." A recent call for papers asks for papers in areas such as "critical reflections on post-digital futures rendered as Design Fictions", design as an alternative to the "engineering creativity" within hard science fiction and reflections on "Design Fictions as methodology and on the ways in which fictional constructs and diegetic prototypes might open design discourse on cybernetic futures".[5] The interests in a speculative field of design, and in speculative fiction as a design methodology, is to me an indication that we cannot assume that we now know the issues we are facing well enough to turn to problem solving. In analogy, architecture is faced with issues beyond providing sustainable shelters; as architects we must continue to seek new challenges. Further development within a speculative approach to architectural design is in my mind an important future research area, and a potential mode of architectural practice.

The proposed framework for digital design strategies can be related to existing work within the digital design field in regards to implementation, but to me, the rather narrow focus on digital fabrication tells only half the story. Even though the employment of fabrication technologies suggests a process oriented approach, to me this is mainly manifested in produced artifacts rather than in an understanding and dissemination of the processes that surround implemented digital design. With the opportunity to act as a 'broker,' to use Wenger's term, and facilitate the integration of digital and parametric design techniques within a large architectural practice, I have come to understand the necessity not only for specialists able to develop parametric systems on the fly, but for a strategic understanding of how to make such development a value adding part of an overall project. In extension, there is a need to make such efforts part of the business side of a practice, and communicate new offers from an architectural perspective, rather than a pure process or economically oriented one. There lies great future research potential within this strategic field, partly in the 'field testing' of the operational strategies outlined in this thesis, but also in the employment of the conditions of a 'main stream' architectural practice as a potential new venue for architectural innovation within the digital design field. The third potential future research field regards the notion of the 'digital design trope,' in my mind a powerful concept that relate strongly to my earlier notions of the prototype. I believe this idea can be further advanced, and deserves its own in depth study, and through this could become a definition applicable in discourse and practice alike. This will require further definitions beyond the examples form references and included design projects covered in the thesis, but I believe it may suggest an alternate approach to future discussions on digital design processes and methods in relation to design outcome. The digital design trope is not normative, nor does it belong to a particular style or discursive approach. In analogy to the use of tropes in literature, it remains potential rather than becoming a cliché, and it may indicate a design concept that becomes transformative, and alters the preconceived image of its purpose. I am aware that this has only lightly been touched upon in the thesis, but I believe that these initial outlines suggest a future potential for the concept.

Theses, Discourses and Research-by-Design

Finally, there is something to be said about the format of the thesis as well, in regards to its structure as well as to its type. While providing neither complete recipes nor advanced discursive critical approaches, my ambition is that this doctoral thesis can provide examples and ideas of how design work and academic writing may been affiliated in an associative, yet rigorous way. The licentiate thesis has been described as creating three well defined spaces of knowledge, the third being established through the links associating the two books; exposing the design projects without any legitimizing or contextualizing (in respects to the overall thesis) layers, but also suffering from being ephemeral and unarticulated.[6] The dialogue that has been established between the two new sections of the doctoral thesis, and partly also recalls the previous two, is articulating the relation between all four parts of the doctoral thesis, and also traces the research process through the design project enquiries. The design projects are queried about how they relate to, illustrate, exemplify or contradict the issues discussed in each chapter. They do not prove arguments, nor do they provide concluding evidence; they are instead given equal status to external references and my own arguments.

From an academic and conceptual standpoint, a number of references in terms of academic dissertations have been important in the conception, development and formatting of the thesis. Jonathan Hill's PhD thesis was an early reference and inspiration for the relation between design projects and text, even though his thesis constitutes a work of primarily critical nature.[7] To me, the project and text in his thesis are two parallel ventures to in the formation of a critique to the protection of the legal status of the architect, one conceptual, one academic. The parallel existence of these two thesis aspects has been a strong influence during the

development of both my dissertations, but I was seeking a more direct association between my writing and my engagement in architectural design. My former main supervisor and current secondary advisor Katja Tollmar Grillner's thesis constructed the main body of work through a series of situated dialogues, between herself and historical characters in a fictional way. What she accomplished in terms of the narrative as a constructive means could serve as an important reference for future explorations of the speculative approach I have suggested, but for the purposes if this thesis, it was beyond my scope as well as my capacity.[8] Of equal relevance is the thesis of Malin Zimm, which is considering remediation and narrativity, as well as real and virtual spaces of the late 19th century. Her association to contemporary science fiction concepts was an early influence, but her understanding of narratives in relation to new and old media is far beyond what I have accomplished.[9] Pia Ednie-Brown employs design projects (the work of her students as well as others) to inform her discursive approach in her doctoral thesis. As referred to before, she suggested an approach to the notion of affect that in essence brings an aesthetic discourse into the actual design process, and possibly as a strategic asset.[10]

There are also direct relations to my subject matter, the digital design field, either at a conceptual level (Zimm) or direct level (Ednie-Brown) among the previous references, but I can also relate my work to a number of more technically oriented dissertations. Axel Kilian, once my tutor at a SmartGeometry event, assembles a number of related and unrelated projects in his doctoral thesis, and this approach in which disparate projects were allowed to contribute in their own unique way was an important discovery to me.[11] Oliver Tessman's doctoral thesis employs his own design work as well as that of his students in his exploration of the collaboration enabling capacity of digital design tools, and while his field regards structural engineering, his approach is primarily architectural.[12] Martijn Veltkamp's thesis considers the use of schemes, systems and prototypes for structural engineering and his in-depth studies of geometry have proven valuable for may research and teaching alike.[13] As discussed previously, the doctoral thesis of Roland Hudson has been of particular interest in regards to the formulation of strategies within the digital design field, and while we have quite different approaches, I have found his work important both in terms of the subject matter and in his rigorous approach to sources and formatting.

With these references in mind, I would like to define my own doctoral thesis as an attempt to connect different approaches. This can be identified through my two proposed new research areas that may remain uniquely distinct parts of the thesis, but still have been associated to certain extent. It can also be seen in the way I have attempted to relate architectural discourse with more technical approaches, in which I hope to communicate that I find them both equally relevant for future development, but I would like to see more work that does not present one in favor of the other. Finally, I believe it is present in the way I present the design projects associated to the thesis in relation to my overviews of discourses and research references. To me, these associations between different aspects of the digital design field, and different research approaches, is my final contribution to the research-by-design field.

5 'Call for Papers: Design Fictions – Special issue Digital Creativity,' *Digital Creativity*, 22:3, 217-217, 2011
'Diegetic Prototypes' have been suggested by David Kirby as "cinematic depictions of future technologies", with especially evident performative aspects because a film's narrative structure contextualizes technologies within the social sphere.
Kirby, David, 'The Future is Now: Diegetic Prototypes and the Role of Popular Films in Generating Real-world Technological Development,' *Social Studies of Science*, vol.40 no 1, 2009, p.41-70

6 Grillner, Katja & Hughes, Rolf, 'Den kritiska textens former i arkitektur-, konst och designforskning,' in *Konst och forskningspolitik – konstnärlig forsknings inför framtiden*, Årsbok kFoU 2009, Vetenskapsrådet

7 Hill, Jonathan, *The Illegal Architect*, Black Dog Publishing, 1998

8 Grillner, Katja, *Ramble, linger and gaze – Dialogues form the landscape garden*, doctoral thesis, KTH School of Architecture, 2000

9 Zimm, Malin, *Losing the Plot: Architecture and Narrativity in Fin-de-Siécle Media Cultures,* doctoral thesis KTH School of Architecture, AXL Books, 2005

10 Ednie-Brown, Pia, *The Aesthetics of Emergence*, doctoral thesis, RMIT University, School of Architecture and Design, http://issuu.com/pia_edniebrown/docs/02whole (9/10 2011)

11 Kilian, Axel, *Design Exploration through Bidirectional Modeling of Constraints*, doctoral thesis, MIT, 2006

12 Tessmann, Oliver, *Collaborative Design Procedures for Architects and Engineers*, doctoral thesis, ETH, 2008

13 Veltkamp, Martijn, *Free Form Structural Design: Schemes, Systems & Prototypes of Structures for Irregular Shaped Buildings*, doctoral thesis, TU Delft, 2007

The Projects II book present architectural design projects that have been important sources for the concepts and definitions developed during the later stage of the doctoral project. Building on the earlier work in the Licentiate thesis Architectural Prototypes, the projects again can be regarded as assemblies of "related research tasks". The previous thesis introduced the idea of design loops; a way to break down different aspects of a larger project for legibility and for allow-ing a clearer comparison between projects. This second thesis introduces a number of different aspect as ways to contextualize and give purpose to digital design techniques, and in a way make the design loops more operational as design instruments for design work, shifting the focus from a reflective understanding and dissemination of projects completed, to an outline of future design processes. The 'design narrative' presents the design history of each project in terms relevant to the overall argument, and is regarded of strategic importance also for future use [Contexts II: p.83]. 'Digital design techniques' identify the main techniques employed [Contexts II: p.25]. The 'architectural performance' regards the design outcome in relation to the design process. The 'speculative aspects' relate to discussions in the 'Informed Speculations' chapter of the Contexts II section, and may regard conceptual approaches and speculation within the design process as well as part of the design outcome [Contexts II: p.60]. 'Digital design strategies' refer to the different levels of operational digital design strategies discussed in 'Strategic Implementations' chapter [Contexts II: p.80], and are also listed at the end of the Projects II section [Projects II: p.170].

The projects presented in the first Projects book were primarily based on collaborative design work with the participation of the author, all developed in isolated experimental environments. The projects presented in this second Projects book are contextualized either through being student work developed with the author as tutor, in which there is an overarching agenda shared by all students, and a continuous discussion through the reviews, presentations and external evaluation that is part of architectural training, or by being part of live architectural projects through the author's role as director of Dsearch, the digital design development environment within White Arkitekter AB.

Student projects

Teaching in a studio environment allows the integration of design techniques into the design and development of projects that relates to issues external to the digital design field, while exploring how particular design techniques can be part of both conceptual and pragmatic aspects (as opposed to shorter more focused courses on techniques). The dual ambition is to train students in the general field of architecture (who will deliver a comprehensive project) as well as give them skills identified as important for near future practice. In addition, the studio / unit situation becomes an environment for research into architectural applications of new technologies, relevant architectural responses to urgent issues in society and into architectural education in itself.

One of the student projects originates from Diploma Unit 16 at the Architectural Association, where the author was a unit master 2008 – 2010. The overarching theme of the unit for the period 2008 – 2011 has been Adaptive Ecologies, with different sub themes for each year. The exploration of the "affects and emerging ecologies of Extreme Environments", through computational and material means has been a part of the overall agenda since the inception if the unit in 2005. In 2008, the scope was slightly shifted to not only mitigate and explore the effects of climate change and natural catastrophes, but also approach how society would adapt, and what measures architecture in a broader sense could provide. With an outset in the idea of the composite, it was applied "to material research, digital methodology, programmatic organization, architectural performance and formal as well as spatial quality, as students explore intricately and/or reciprocally associated information and phenomena in both a parallel and iterative manner by exploiting the opportunities afforded by parametric modeling techniques." The design research of the unit was identified as a search for "innovation in computational technique, formal repertoire, tectonics or architectonics and organizations capable of coping with the contingencies of climatic change ... ... The investigation of contingencies further promotes designs capable of coping with a multiplicity of future conditions, rendering singular performances and components obsolete. In contrast to primitives we seek the investigation of indeterminate composites with the potential of co-possible organizations and behaviors." [1]

The multiple agenda combining computational and digital innovation for design, analysis and production with responses to urgent climatic issues required the individual student to locate a situation in which he/she would deploy the individual project. The analysis of a given site and local condition coupled with a thesis; a concept and later also a strategy for how an architectural design project may explore critical issues and propose an architecture and a methodology of relevance. This in turn provides an informed context to the design development and technical applications, and provides a background to how the proposal can be evaluated. The notion of the composite was employed as material principle, digital technique and systemic principle. The idea of adaptive architectural ecologies suggested the design of architectural systems with high specificity (in regards to designed components as well as technical and architectural performance) that could be re-deployed in different contexts.

Remaining student projects were developed as part of KTH studio 11 under the theme 'Architectures of Interdisciplinarity'. The relevance of digital methods as part of supporting interdisciplinary collaboration were at the core of the studio, further emphasized by the constitution of the team of tutors; combining architects with structural engineers, and further supported by a network of specialists. Again, techniques and methods were targeted towards issues deemed to be especially relevant in current society, in this case industrial architecture and in particular the role of architecture in the development of Energy from Waste heat and power plants. "Studio 11 seeks to critically capitalize from its 'in-between' position, in the sense industry- academia network as well as interdisciplinary (primarily architecture-engineering) basis in order to create the best possible (informed, non-biased) environment for informed innovation to take place. It seeks a holistic synthesis of technological investigation and design, using projective and case-based learning to research the socio-technological implications of design strategies." [2]

Projects II

Over the full year, students were first introduced to design techniques and spatial concepts through a series of workshops, then to the industrial architecture of EfW facilities through the design of a visitors centre at an existing facility, in preparation for the spring project involving the proposal for a complete facility. While the overarching theme and typology of the design proposals were pre-deter--mined, the students were asked to integrate additional programs to their design, and allocate relevant strategies for design, structural performance and environmental issues at the core of their designs.

Practice based projects

Several of the included projects were developed by the author as part of Dsearch, a recently established environment for digital design development within White arkitekter AB. Method development in Dsearch is closely associated to project development, providing a context for exploration and a continuous testing ground. Operating on internal budgets allows time spent on innovative development outside of the limits of live projects, yet provides relevant issues for exploration. The link between design techniques and project implementation is crucial however, and requires careful definitions on how techniques can be applied in a given project, as well as an equally careful evaluation of the potential of a project for deployment. Dsearch, initiated in 2010, currently operates within the practice of White Arkitekter AB, which can be seen as an inner market. With small resources there is also a necessity to establish external networks, but most importantly, there is an ongoing work of defining digital design strategies that in several ways coincide with the ambitions of this thesis, at least on a pragmatic level. "Dsearch is a digitally based development environment and a network within White arkitekter AB, with the aim to continuously develop methodology and design tools in order to ensure that White retains a high international standard in regards to project design and implementation. This is achieved through the formulation of strategies, independent method development and direct support in projects." [3]

The projects documented and evaluated originating from Dsearch activities are part of an ongoing build up of technique resources, and as such can be seen as embryos to strategies. They are all seen as assemblies of parametric techniques in response to specific aspects of architectural projects within the firm, and explore issues of refined design opportunities not before available within the practice, as well as formalized design techniques that enable design re-use of processes rather than solutions. As such, they can be re-aligned for new purposes, and are vital parts of the digital design strategies that are being formed within Dsearch.

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1 Lundberg, Jonas; Runberger, Jonas; Yau, Andrew, *Adaptive Ecologies 1; Composite Materialities Extended Research Brief*, Architectural Association Diploma unit 16, August 2008

2 Kara, Hanif; Martinsson Achi, Lina; Scott, Paul and Runberger, Jonas, *Architectures of Interdisciplinarity*, main brief, KTH School of Architecture, August 2010

3 Runberger, Jonas, Letter of intent, Dsearch, White Arkitekter AB, September 2010

Flexible Space Frame

Kengo Skorick, student AA DIP16, 2008 – 2009

With an overarching objective of exploring the spatial potential of adaptive structures, the 'Flexible Space frame' project involved the development of a generic space frame system that can be adapted to multiple uses, and through its flexibility could be re-used in alternate scenarios. As a design exploration, it originated in an interest in the performative potentials of composite materials, and a step by step development process involving a series of material / structural and digital / systemic prototypes. The generic system was contextualized through a series of site specific applications.

Design narrative

The initial prototypical study models involved primarily the material performance in a composite of ceramics, latex and fiber, which provided a combination of structurally rigid members and rotational joints, and as a result a flexible structural space frame. An additional system of tension cables provides stability and makes the overall system rigid; these could be manipulated for different spatial configurations. The first iteration used a combination of yarn, woven on a supporting framework, and a matrix of ceramics and focused on adaptive qualities in the system [01 – 04]. The second iteration used a simpler system of threads and sticks, and explored the structural principles [05]. These studies led to the decision to work with flexible joints in the space frame [10 + 11]. In this way, the material strategy became a factor for the design of mechanical joints; the material performance thereby simulated the system performance at full scale.

The physical prototypes were an appropriate testing bed for material and structural performance, but once basic principles were understood, parametric models were needed to test the overall performance of the system as an adaptive structure. By identifying the variations possible in a local component – one joint and its associated structural members and tension cables [07] – simulations of overall system behavior could be developed through a digital model controlled by scripting [08]. A key discovery was that certain units (components around a node) could be controlled and in turn control a field of additional units, thereby allowing local control over a larger volume of units. Through these principles defining, semidefining and defined units were identified [09]. This was studied in digital models and diagrams, and an additional iteration of more precise physical modeling, where structural capacity was again confirmed in a bridge typology [06].

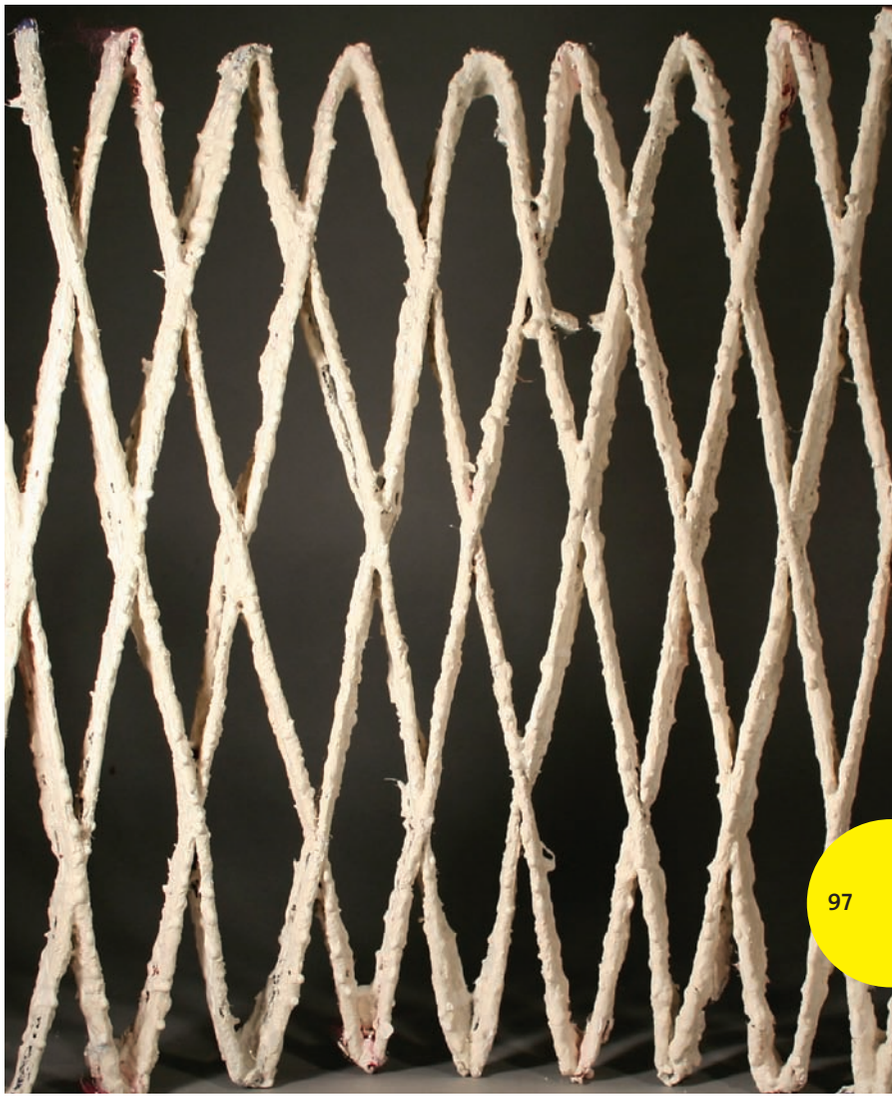
Fabrication principles were first regarded as a direct interpretation of the initial prototypes, experimenting with the possibility of casting the structural ceramic struts around steel cables woven around nodes to allow rotation of the struts [10]. A second proposal was developed in response to cost of time/labor, weight, and structural flaws of the woven joint, by switching to filament winding for manufacturing the struts and using steel ball-socket joints to improve load transfer [11]. The first version was explored through physical prototyping, while the second was based on research on filament winding, with a speculative design that could be tested only in basic form.

The architectural potential of the system was explored through a series of limited design studies. Study 1 deployed the system as roof trusses, and suggested that apertures could be controlled dynamically over a hanging platform [12]. Study 2 suggested a bridging structure in which horizontal and vertical clearance for passage and exact position of a minimal footprint could be controlled, potentially dynamically [13]. Study 3 featured a ramping structure that further tested principles for walking platforms and to some extent enclosure [14]. Study 4 integrated aspects of the previous study into a model that combined enclosure, walkways, relation to ground and circulation with potential programmatic use, and entailed digital as well as physical models through rapid prototyping and cnc-milling [15].

These initial design studies paved the way for two contextualized designs. The selected site on the Tel Aviv waterfront was chosen because of its isolation from the adjacent city by the dividing highway, as well as the programmatic and circulatory layers of the waterfront. The flexible space frame system was proposed to enable free passage between the city and the beach, with the aim to also provide programmatic content of mixed use that would allow new social behaviors and meeting places [16 + 17]. A stretch of waterfront was used for deployment, and a schematic design principle of simpler surfaces was used to provide means of testing the extents of the system as a massing study; a fully detailed model would be far too complex to handle. A second deployment was tested as a proposal entered in the Bexhill-on-Sea Next Wave Shelters & Kiosk architectural competition that asked for a new series of seafront structures for the East Sussex seaside resort [18 + 19]. The design allowed for an additional iteration of design exploration in regards to a restricted program, as well as basic principles for assembly on site.

01 Initial composite material study, static version

02 Initial composite material study, flexible version, eformed



03 Initial composite material study, flexible version

Digital design Techniques

With the focus on composite material behaviors at large scale, this project relied on iterations between physical models, explorative diagrams, direct digital modeling and parametric modeling through scripting. Both physical and digital models were primarily concerned with the adaptive aspects of the systems. [Contexts I : p.22, p.26]

Architectural Performance

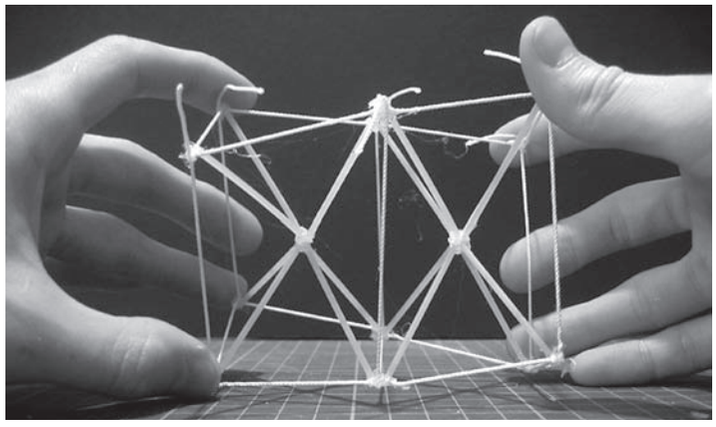
The technical performance of the design system prioritized adaptive characteristics over structural performance. The main aspect of architectural performance, explored through a number of scenarios, regards the network of differentiated passageways that could adapt to different topographical conditions, and be changed over time. [Contexts II: p.38]

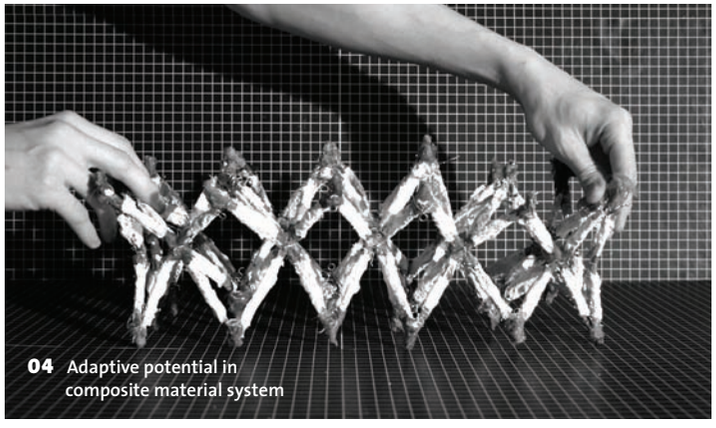
Speculative Design Aspects

With the prototypical approach of this project, each design step introduced another level of speculation, to be informed in the commencing process. The use of carbon fiber filament winding, informed by research into references and extrapolations from its current use through architectural application, indicates a speculative oriented process that may set conditions for future material research. [Contexts II: p.60, p.61]

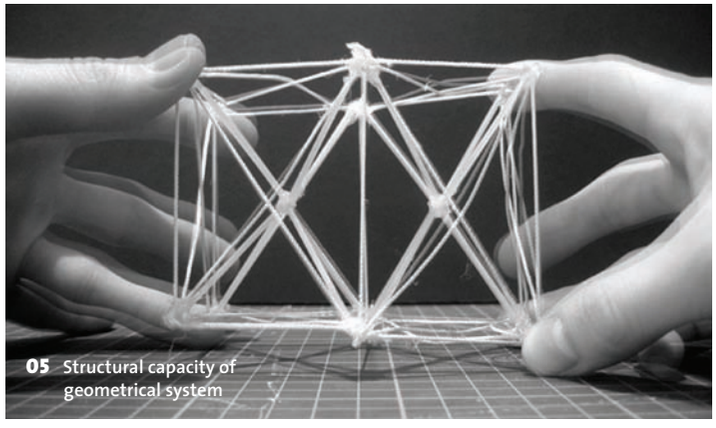
Digital Design Strategies

The project was developed in a strategic manner, in the sense of an initially formed plan for expected design steps, but the innovation driven process also required several course changes. Digital design development was used in several stages and in different forms, and the close association between material and system behavior, and the overall design development makes it difficult to fragment the project into smaller parts. [Contexts II: p.84, p.172]

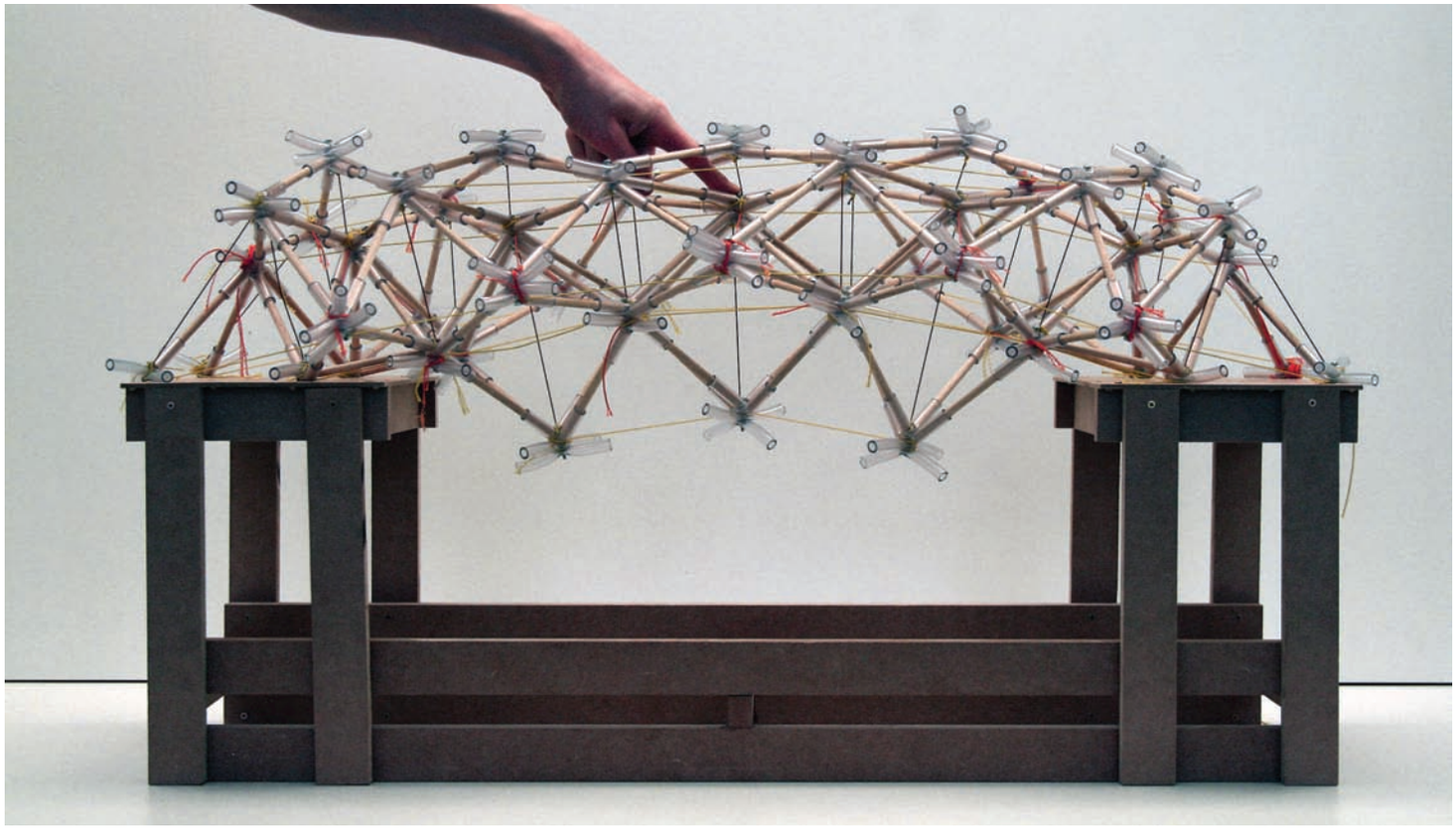




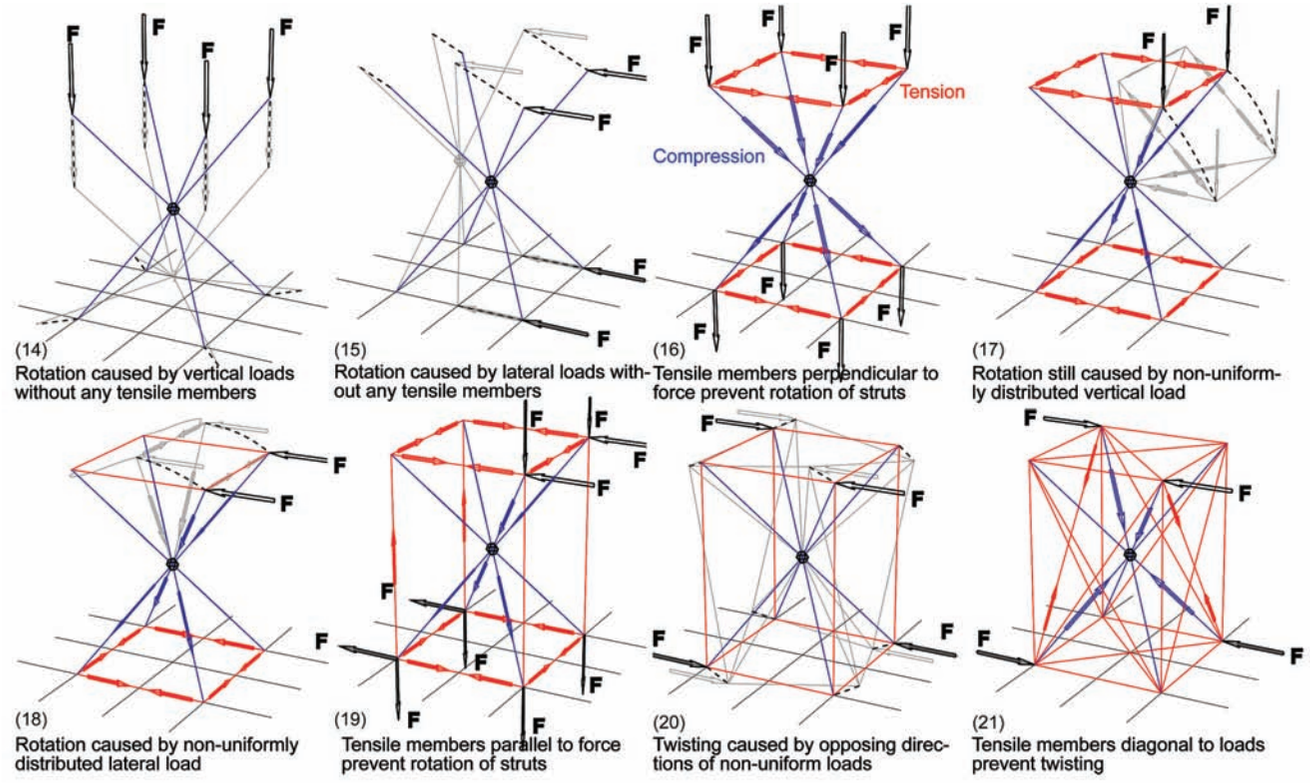
04 Adaptive potential in composite material system



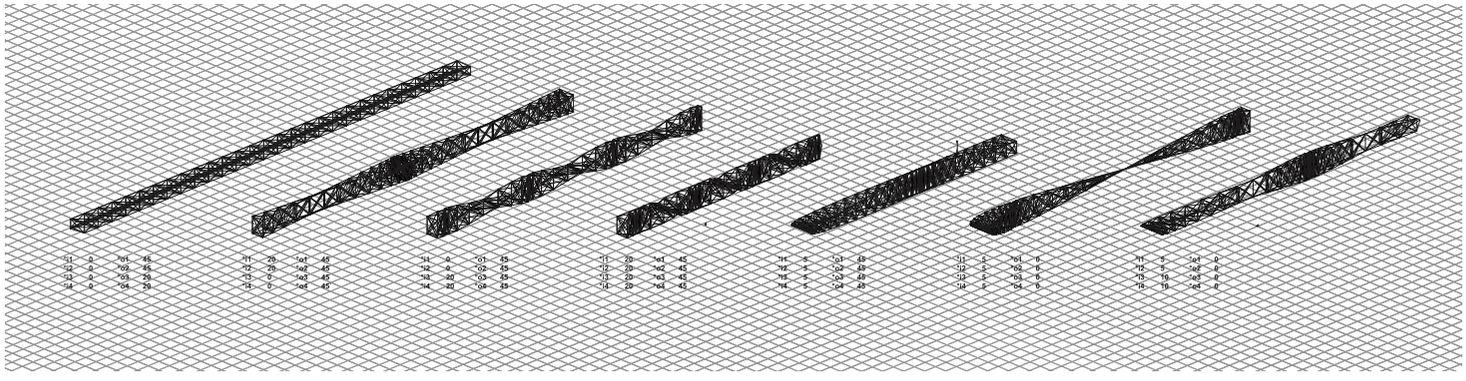
05 Structural capacity of geometrical system



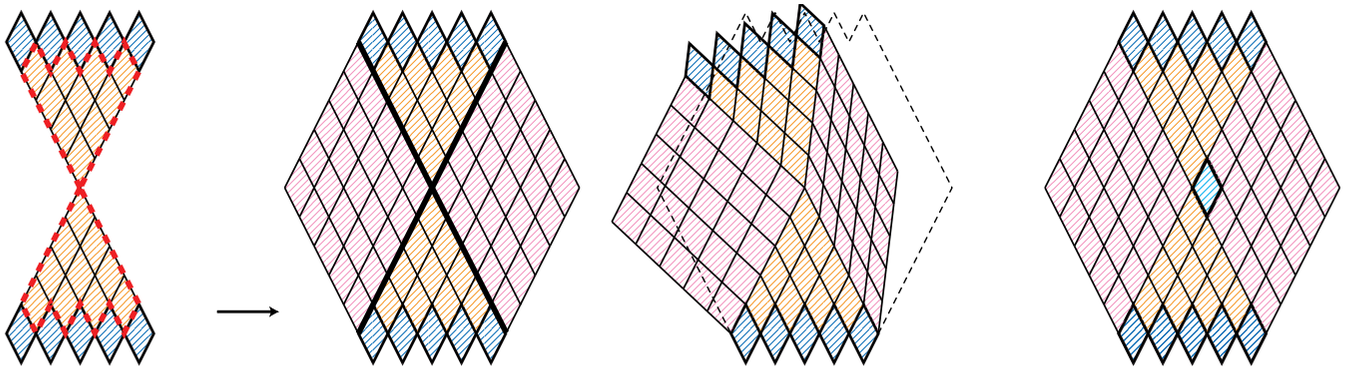
06 Tension cables, configuration and structural capacity



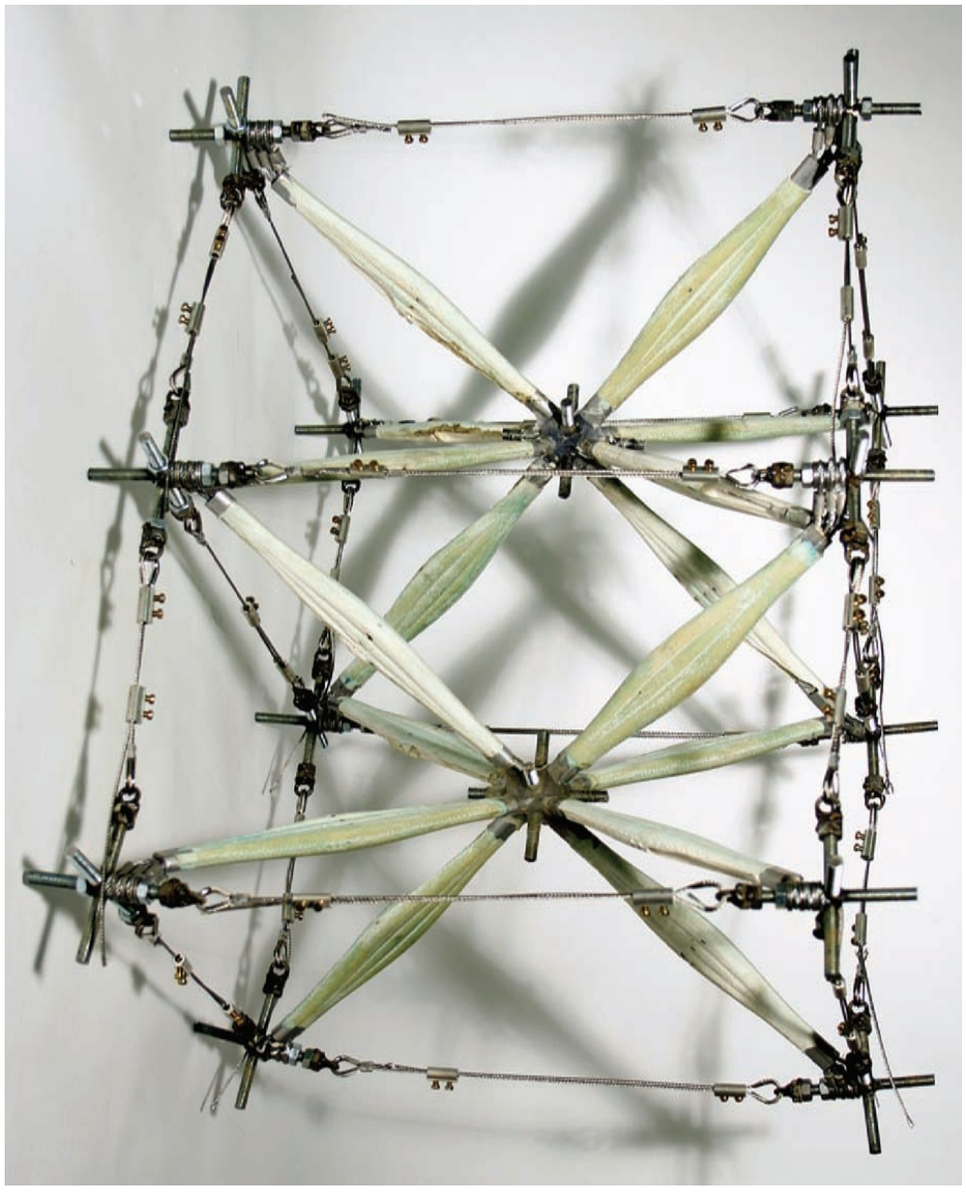
07 Diagramamtic study on adaptive behavior and tension cable requirements

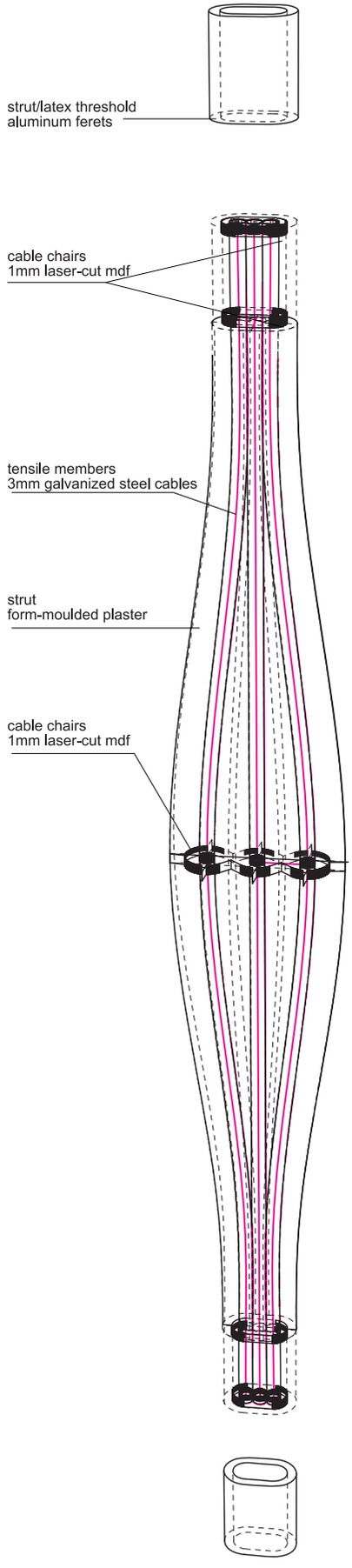


08 Simulation of adaptive principles in scripted models

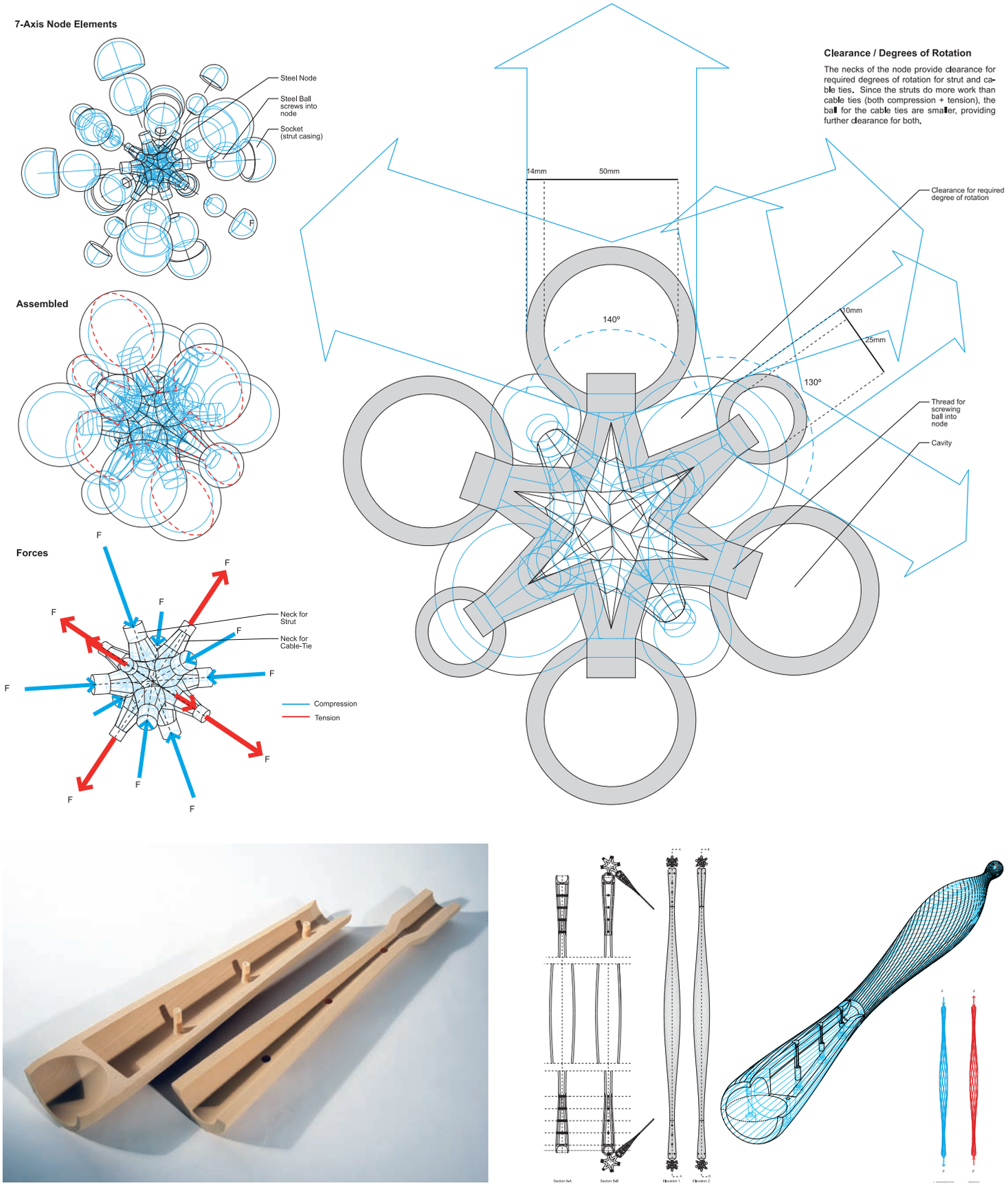


09 Defining (blue), semi-defining (pink) and defined (orange) units

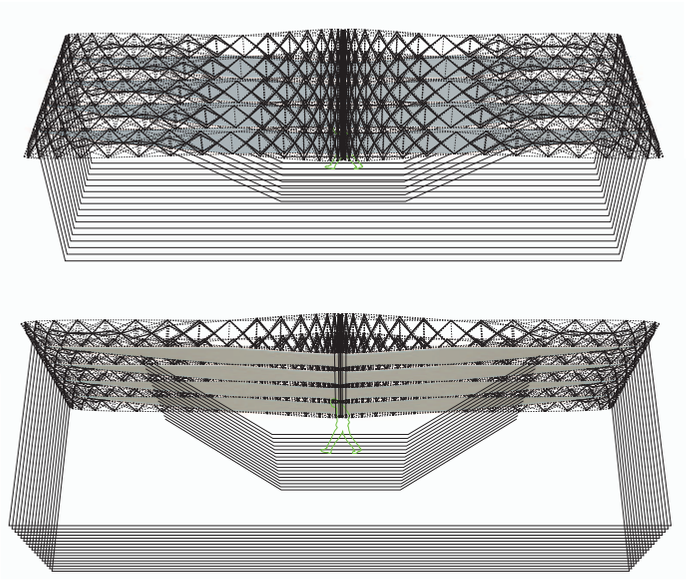


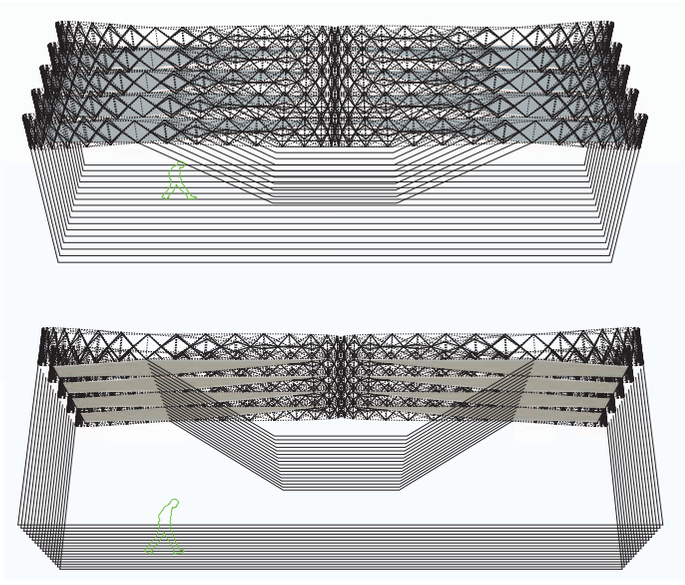


10 First iteration of fabrication studies — steel wiresand ceramic matrix

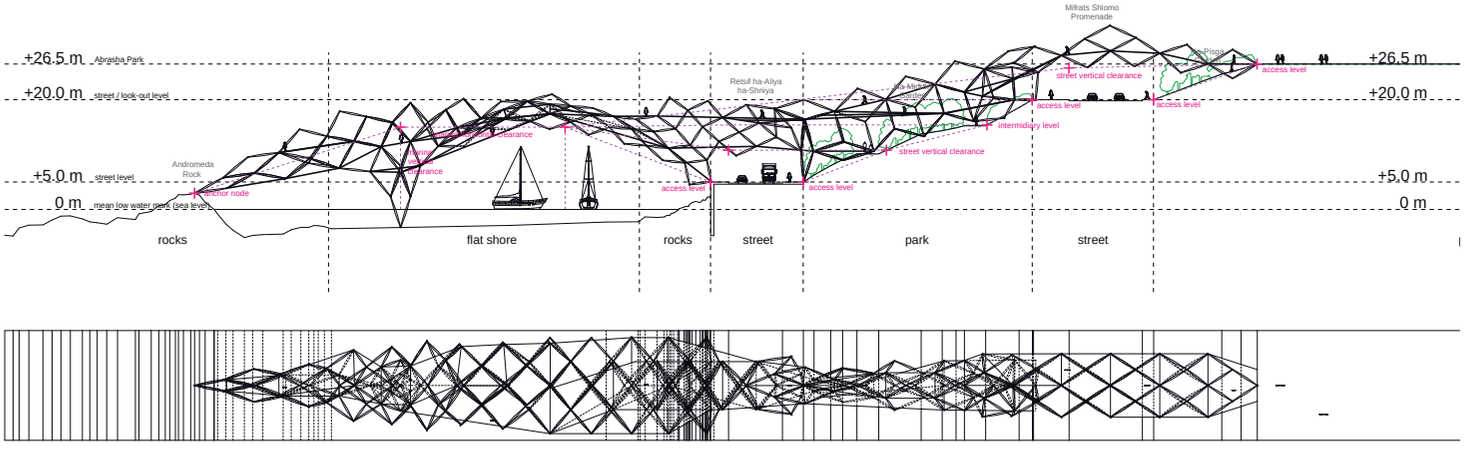


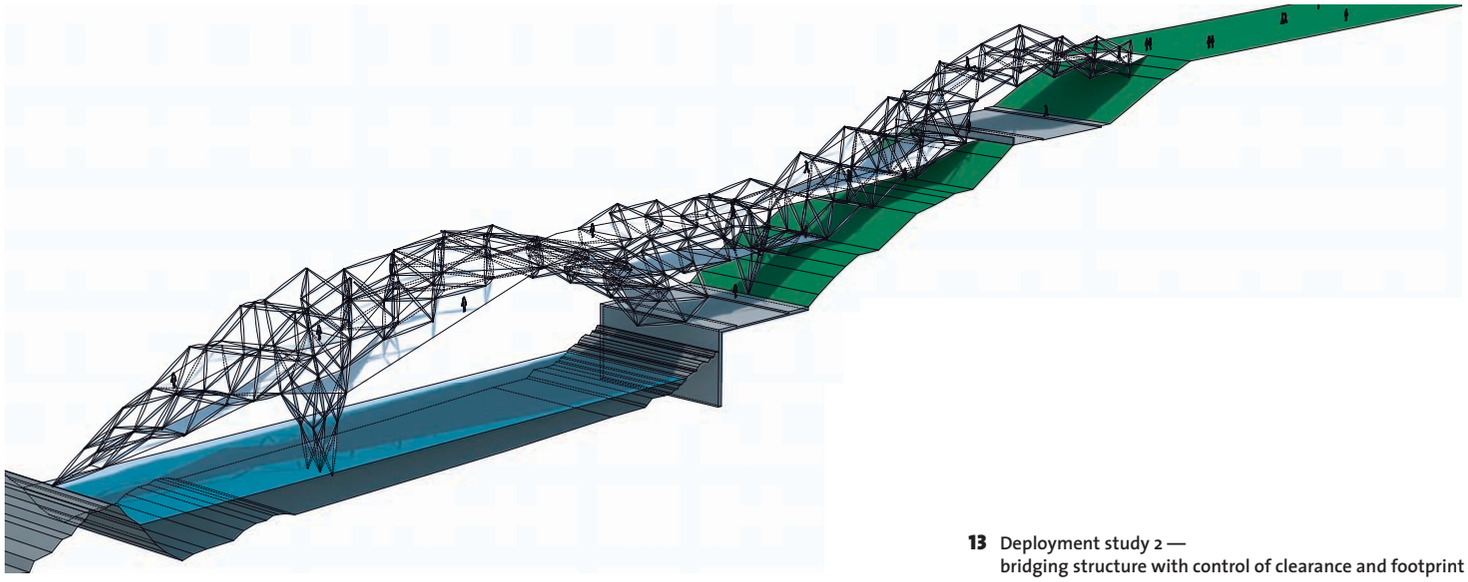
11 Second iteration of fabrication studies — filament winding and steel ball socket joints



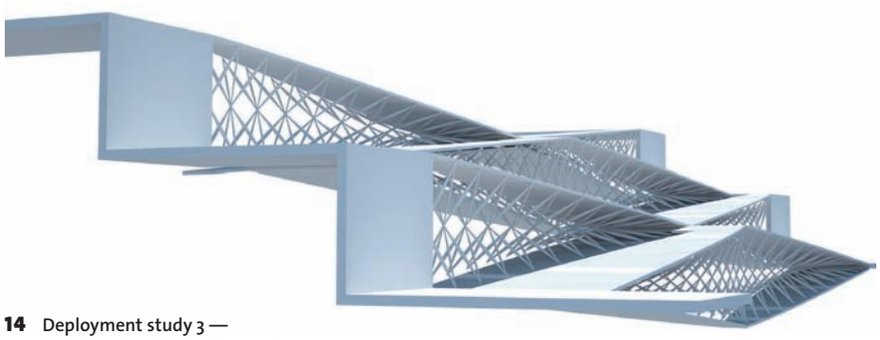


12 Deployment study 1 —
roof trusses with dynamic apertures

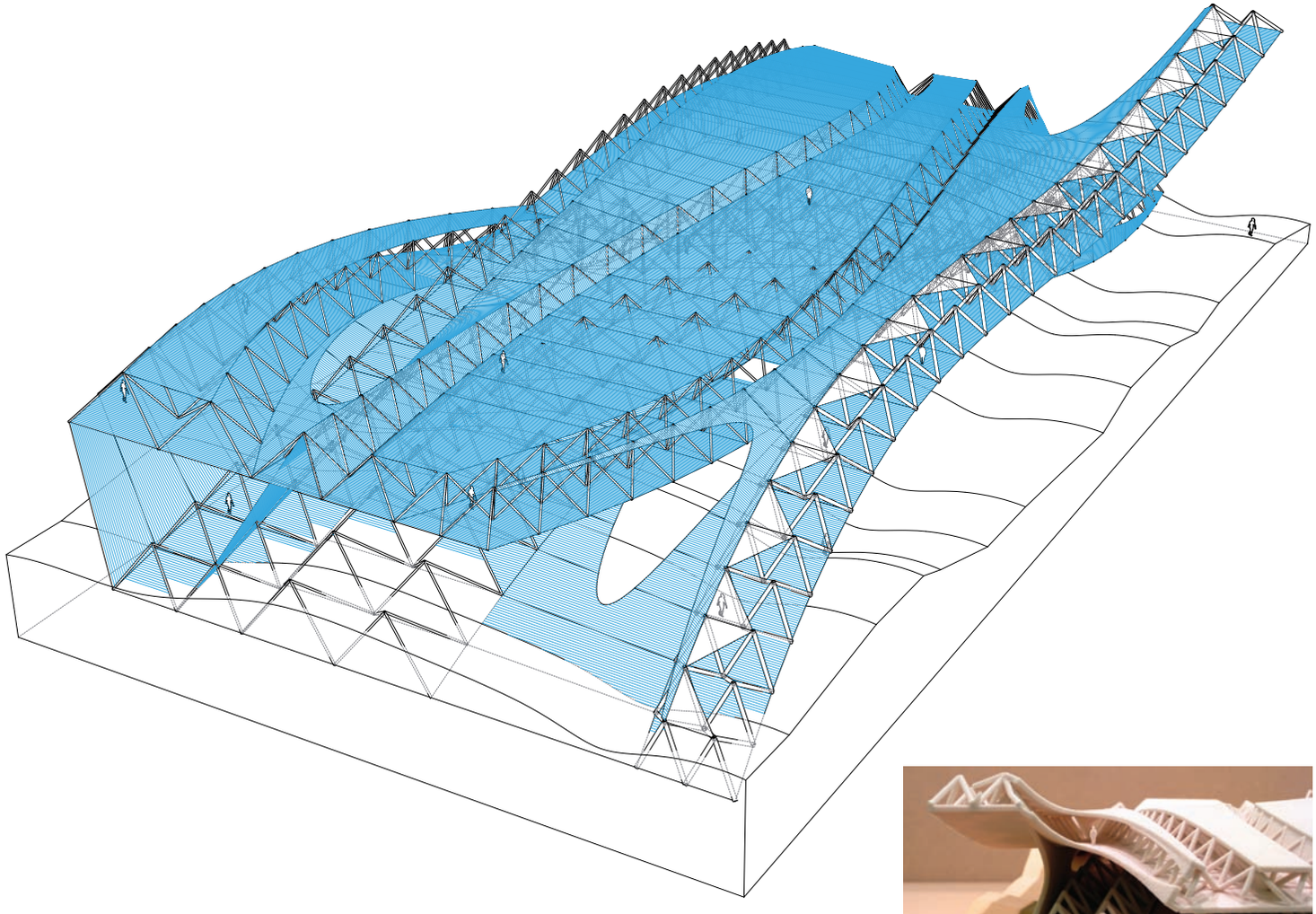




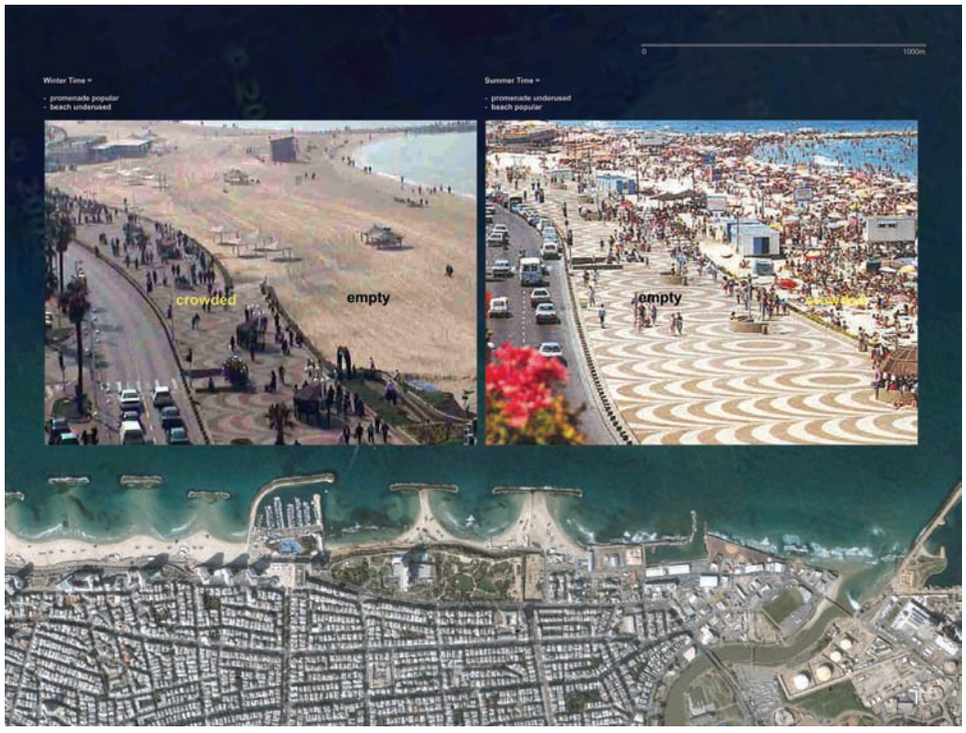
13 Deployment study 2 —
bridging structure with control of clearance and footprint

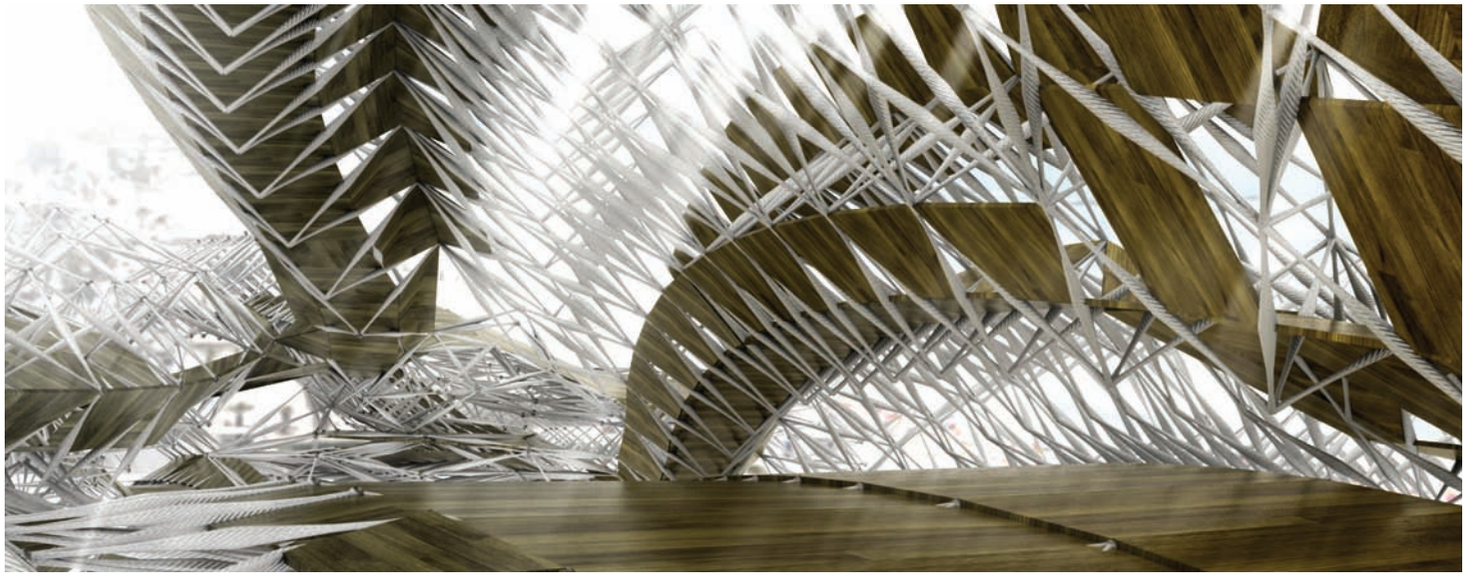


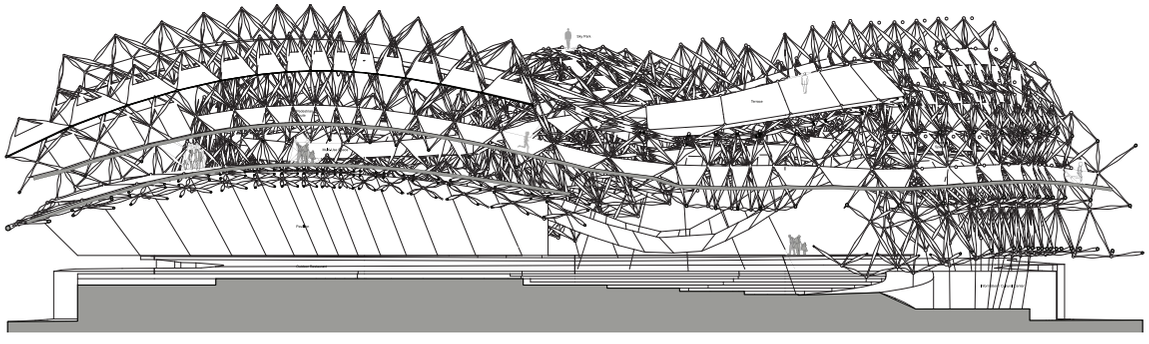
14 Deployment study 3 —
ramping structure with walking
platforms and partial enclosure



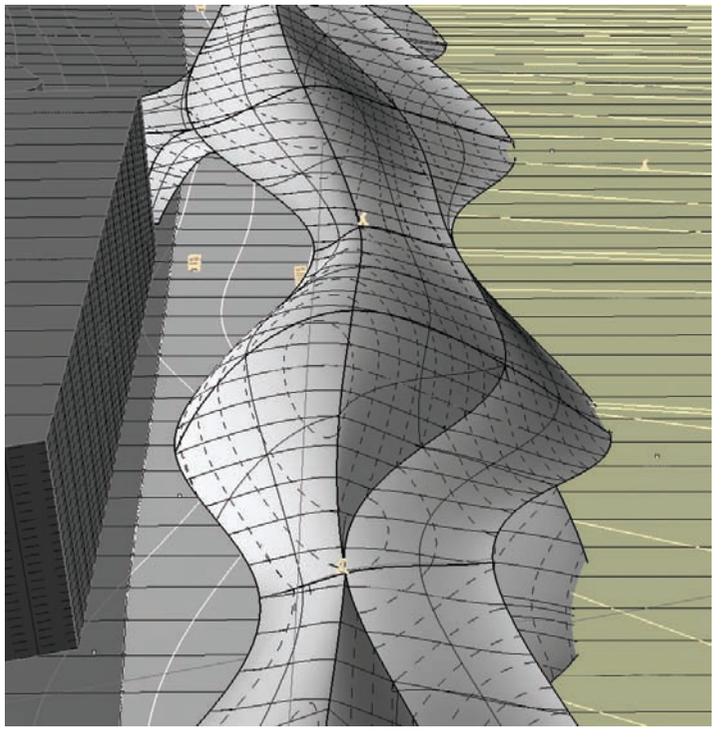
15 Deployment study 4 —
integrated study that adds relation to ground
and circulation, with physical model

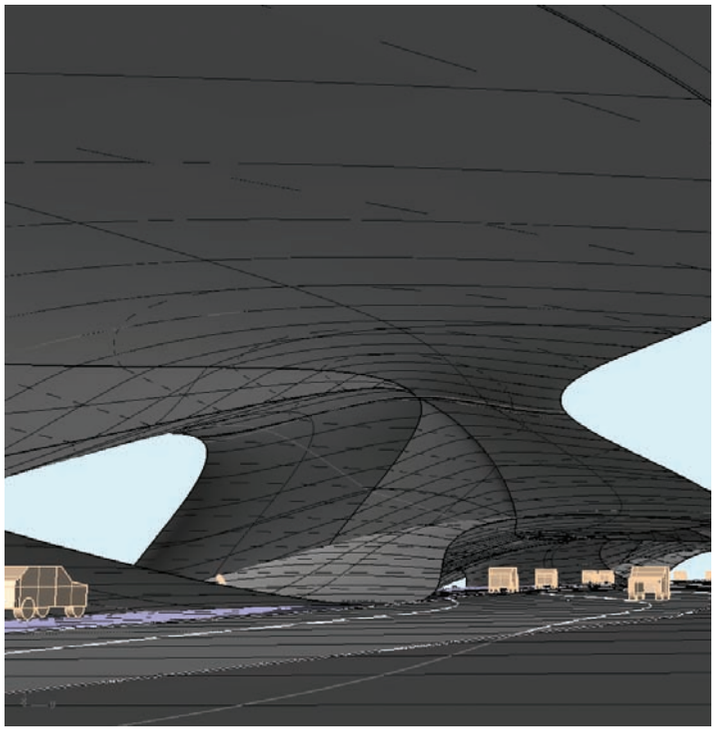


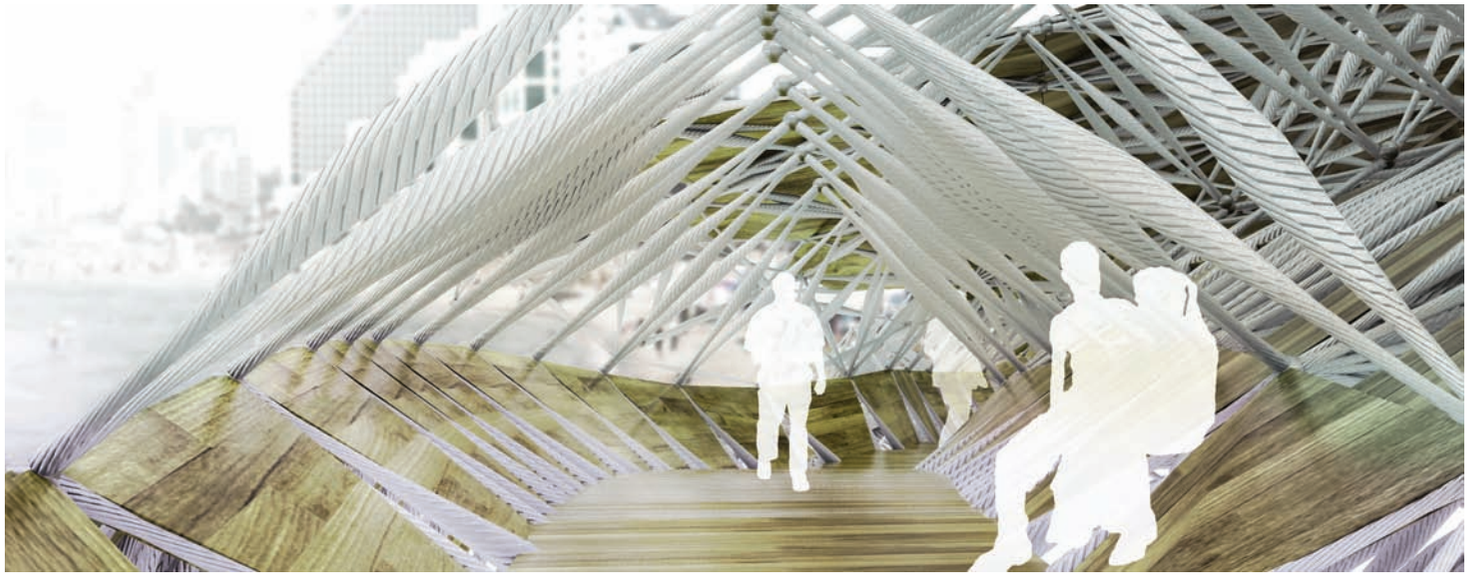




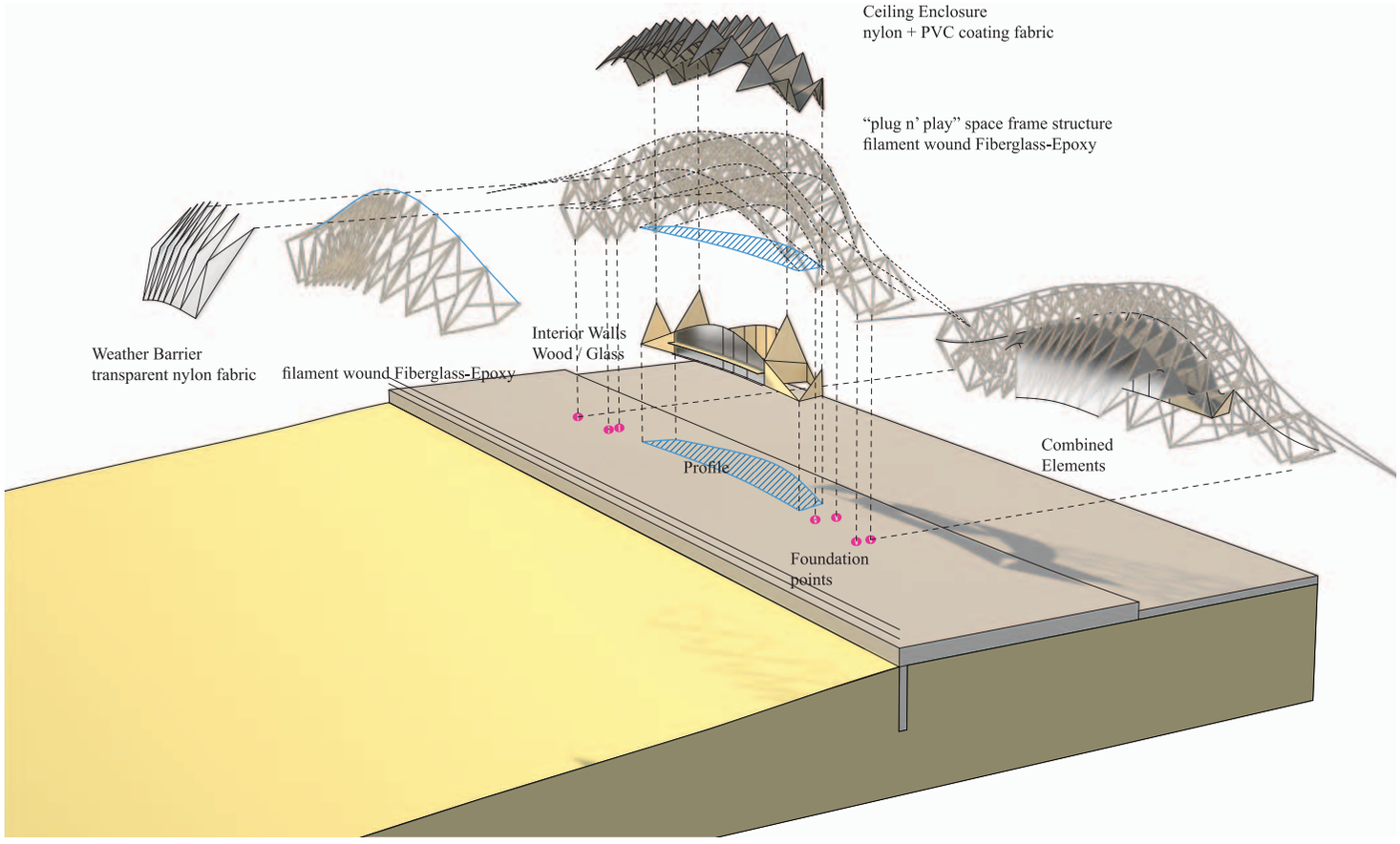
16 Tel Aviv contextualized design — renderings for experiential effect and cross section

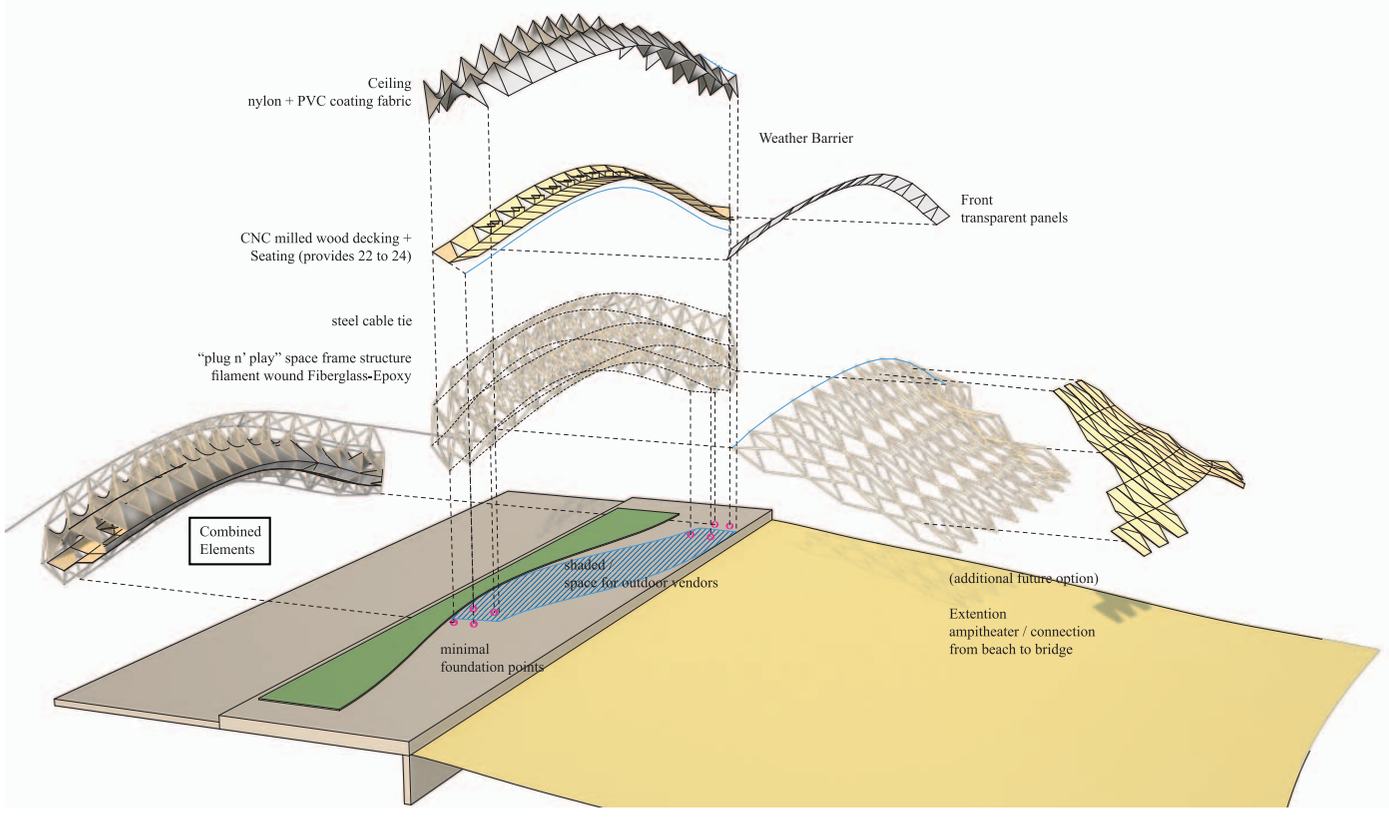




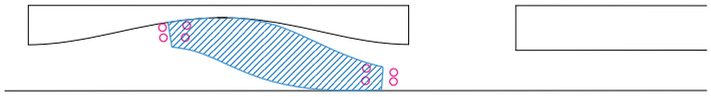


17 Tel Aviv contextualized design — renderings for experiential effect and massing studies

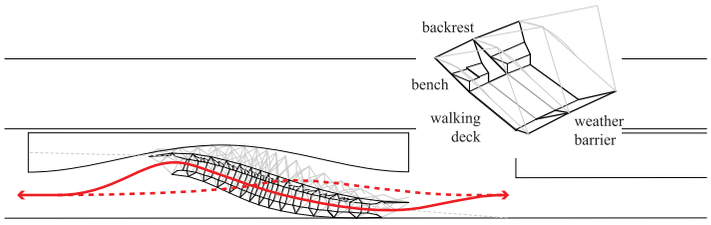




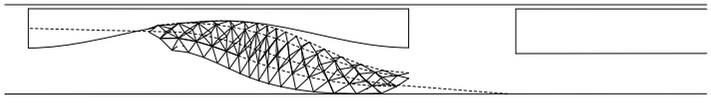
18 **Bexhill-on-Sea contextualized design — breakdowns of components**



+0m
The actual Footprint is small.

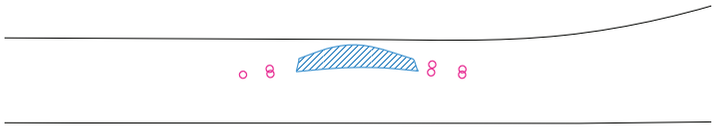


+2m
Pedestrians are tempted to take a smooth detour. Rather than clustered in one location, comfortable wooden benches are distributed horizontally along a ramp, generously wide and shallow enough for wheelchair accessibility.

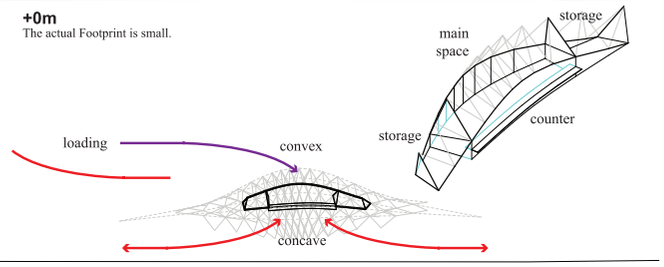


+3m
Shaded from the sun above and protected from the wind in front, the thin strip of space offers both a sense of security as well as the power of nature in front.

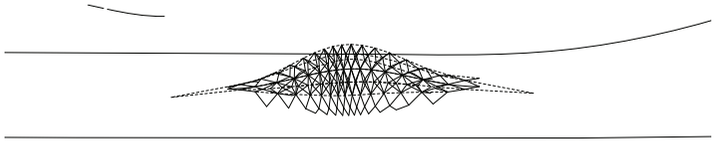
South Elevation
They emerge like a small wave out of the promenade, adding a‘twist’ to the linear experience.



+0m
The actual Footprint is small.

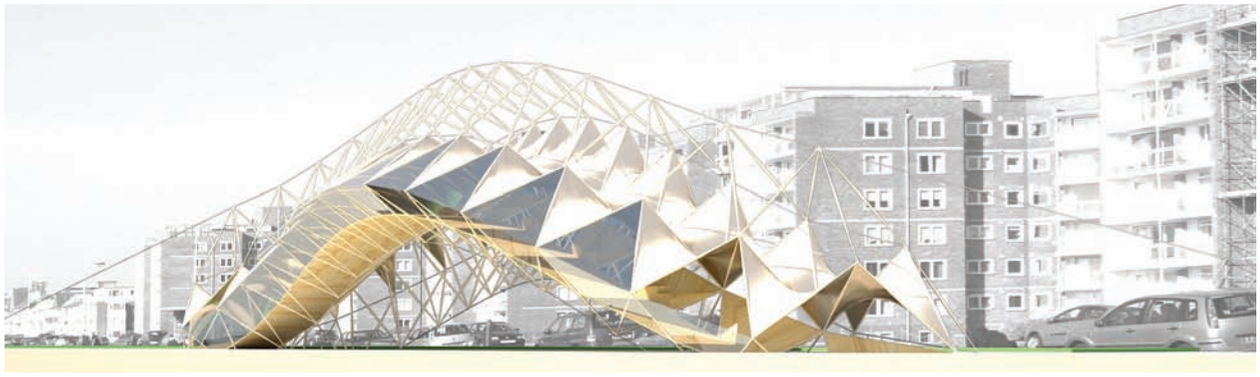


+1m
The concave side brings people inwards towards its sheltered center.
The convex side is pushed towards the street edge, used for loading, and catelevering out towards the street, becoming a sculpture for passing cars.



+3m
Structure adapts into the shape of the context, becoming part of the promenade-scape.

South Elevation
They emerge like a small wave out of the promenade, adding a‘twist’ to the linear experience.



19 Bexhill-on-Sea contextualized design — architectural performance and and renderings for experiential effect

Slumbering Space

Gregoire Stouck, student KTH Studio 11, 2010

Developed during the first semester of the KTH studio, the 'Slumbering Space' project was initiated in a formal generation which set the framework for a series of design iterations. While the design development followed an explorative principle and in succession added additional complexity to the project, an overall comprehensive and integrative design strategy that relies on the direct exchange of data as well as project specific design configurations can be identified as a future potential.

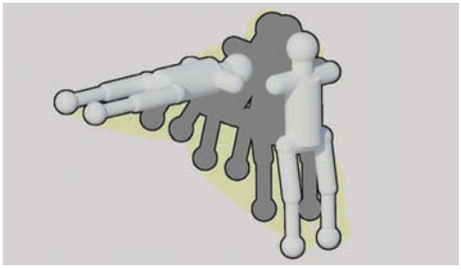
Design narrative

This is the first presented project developed in the primer workshops of KTH studio 11, introducing students to digital design techniques and concepts. The student in this case had the initial ambition to make direct, and if possible explicit, connections between design and evaluation models. The starting point in the conditions of sleeping and being awake was translated into horizontal and vertical orientation, wide vs. narrow and dim vs. bright light. The initial generative model was set up as a linear animation sequence mimicking the movement of the body from a sleeping horizontal position to an awake, vertical position. This model also controlled the way the envelope related to this transformation. To avoid a too literal application, the spatial envelope draping the different states of the human body was scaled up with a factor of five, keeping the formal aspects but allowing movement within the space. This close to arbitrary generation did provide qualities that were enhanced through the later steps, and challenges such as how surfaces for walking can be designed, but for the sake of the project, its most important duty was to set up a spatial model for further development [01 – 04]. The overall formal envelope was divided into smaller components in the form of vertical ribbons, and in the transition zone featuring high formal variation the ribbons could be manipulated to form a walkway with steps [03]. The separation of the strips allowed for light to enter the interior of the pavilion, which also accentuated the overall form [05]. The overall structure of the pavilion was proposed to consist of three layers. The innermost ribbons would be semi-transparent and completely closed in most situations. The mid layer of ribbons would add local rigidness, be opaque and vary in width for light control. The outermost layer of frames is the main structure, and would follow the overall form but with a perpendicular orientation to the other layers and variation of thickness in relation to the structural needs [06]. Apart from the gradual shift between spatial configuration and light admission, the entrance was treated as a specific solution. The structural and enclosing layers were here delaminate from the innermost layer, creating a pocket that gives access from the side of the pavilion, directing the movement of visitors into the longitudinal axis, but facing away from the slumbering part of the building [7 – 9].

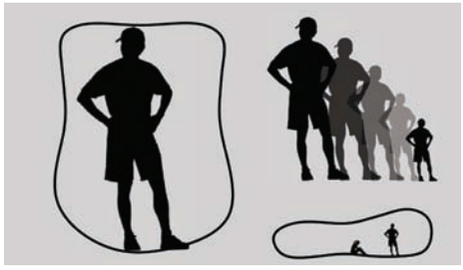
Parametric control beyond the generation of the initial spatial envelope was set up for three main areas. The gradation of aperture through the differentiation of width of the mid layer ribbons allowed local control of light through simple and direct parametric control [13]. A local control of the geometry of the mid and outer layer through the gradual displacement of points in the direction of the curve normal provided the basis for a new set of ribbons for the entrance part of the pavilion [11]. Here, the structural and aperture strategies are hybridized to a specific configuration that allows entry through delamination. In the way the parametric system set up for this in effect was a reconfiguration of selected bands, it facilitated a local additional iteration of the formal generation of the envelope, affecting the structural depth as a result of this. In a way this part of the project was speculating on a more interlaced parametric system, where alternate formal solutions would affect the parametric systems part of the different strategies at play.

For the overall structural capacity, each section was exported to structural analysis software for an analysis of deflection depending on curvature and weight. The structural strategy was based on the banding concept with local variation of structural depth. The analysis of local deflection could be directly fed back into the parametric design model in order to define the structural depth, as the basis for the outer perimeter of the structural frames [12], allowing inflection to parametrically adjust to alternate envelope forms.

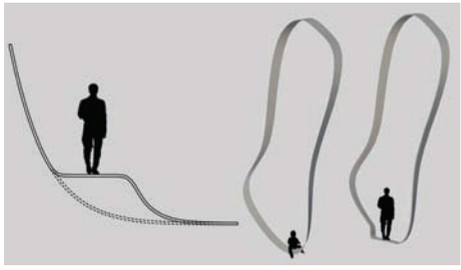
The principle of delamination was also used for the creation of stairs and walkways in the interior [03], as well as to create the supporting structure for the elevated space representing the 'asleep' condition [08]. While materials were not explored further, the design principles suggest a rigid frame for the outer layer, and a more flexible material from the two remaining layers, one of which would be transparent. With a focus on the expected experiential effects, in particular in regards to the mid layer differentiation for light and the overall form of the envelope, the differentiation of the structural frames also articulated the depth of the envelope as seen from the outside, and the admission of light by their capacity as shading devices [10 + 14 – 16]. The longitudinal approach, and the decision to place the entrance on the side of the pavilion, suggests that the project could be a prototype for any kind of passage from one space to another, where the two primary spatial conditions could be altered to fit two existing conditions.



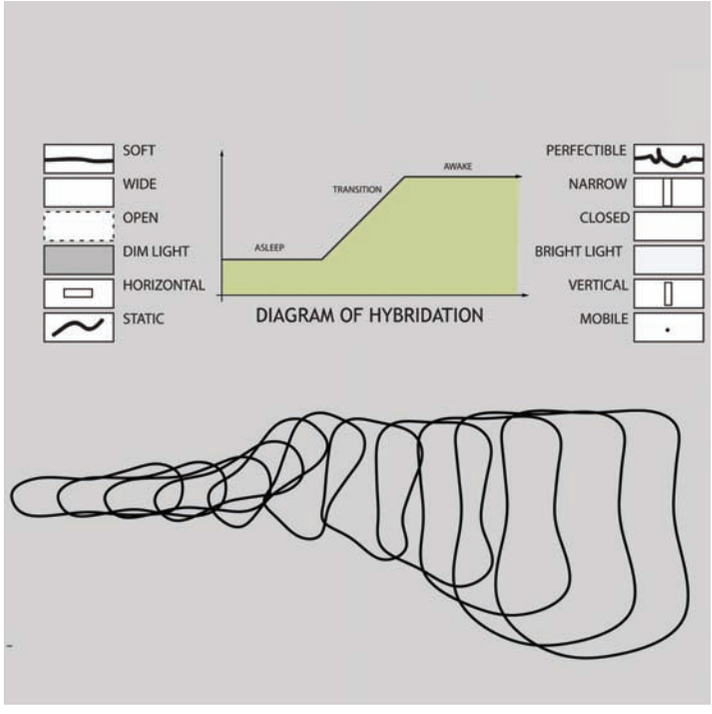
01 Initial mapping of the states of the human body



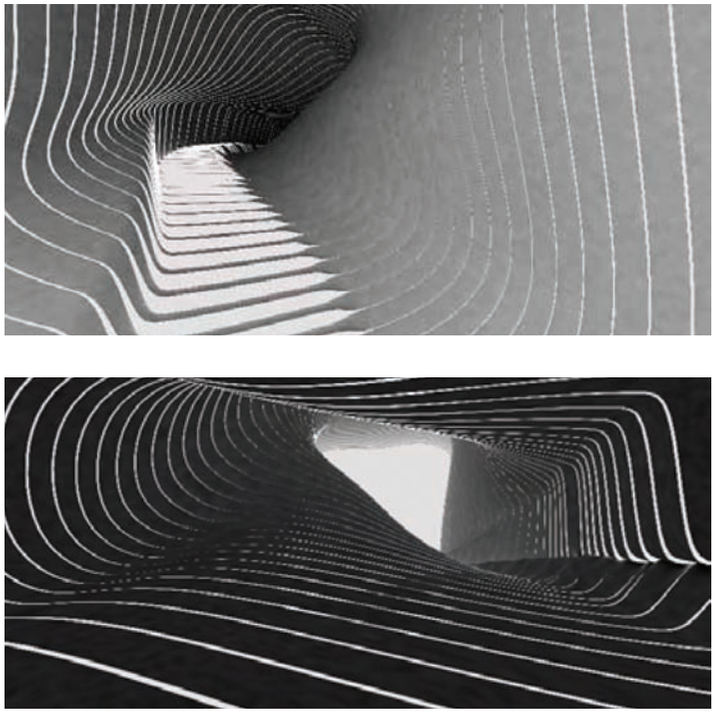
02 Vertical strips transformed into walkway



03 Vertical strips following the formal envelope transformed into walkway



04 Derived qualities and formal envelope



05 Separation of strips for formal accentuation and light apertures

Digital design Techniques

In the step-by-step development of the project parametric models of different characteristics were developed, and partly associated. As such, it can be regarded as a prototype for a compound model, in that analytical software (primarily structural performance) had a direct design input. [Contexts II: p.22, p.26]

Architectural Performance

With formal variation as a driver, and structural performance as analytical feedback that also articulates the exteriors, the architectural qualities arise in the combination of all elements in a way that enables the smooth transition from one space to the other, employing the control of daylight to emphasize this.
[Contexts II: p.38]

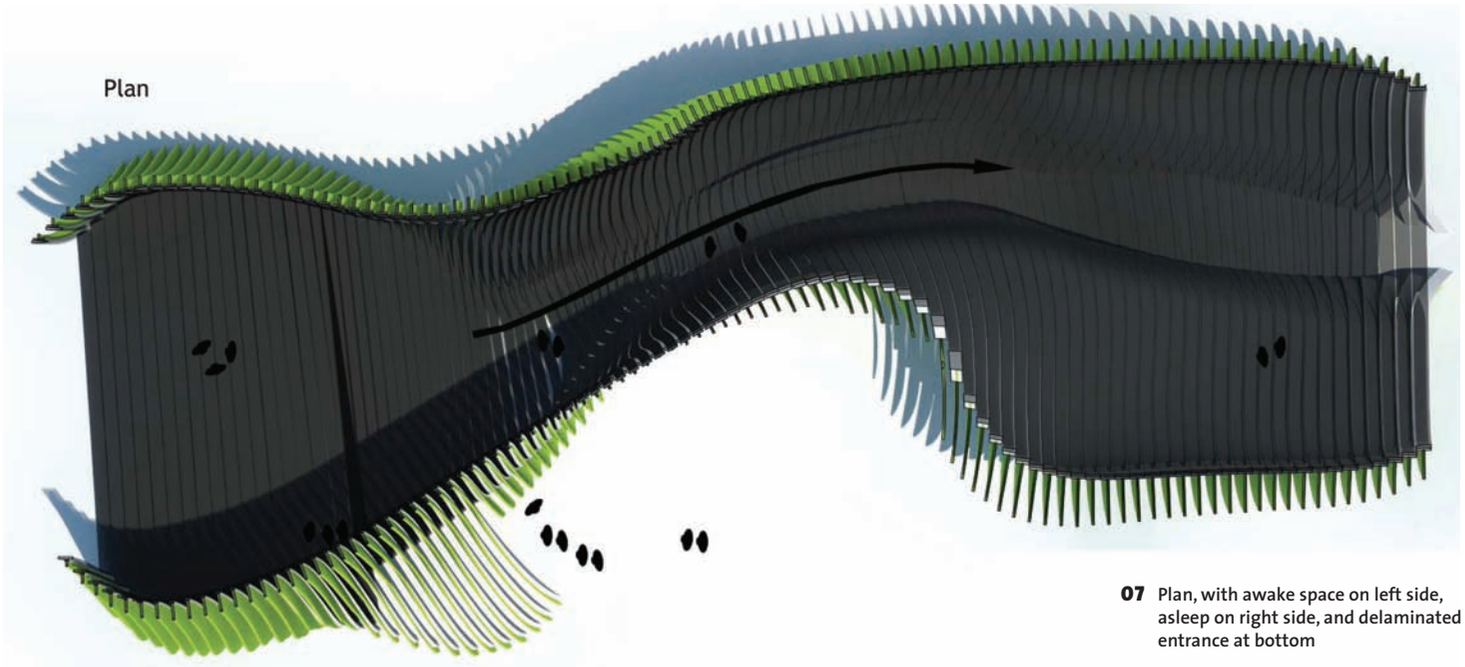
Speculative Design Aspects

The project includes a potential extrapolation on the integration of design tools; a further development could entail a fully integrated compound system, which would automatically adapt structural frames depending on structural performance evaluation.
[Contexts II: p.60, p.60]

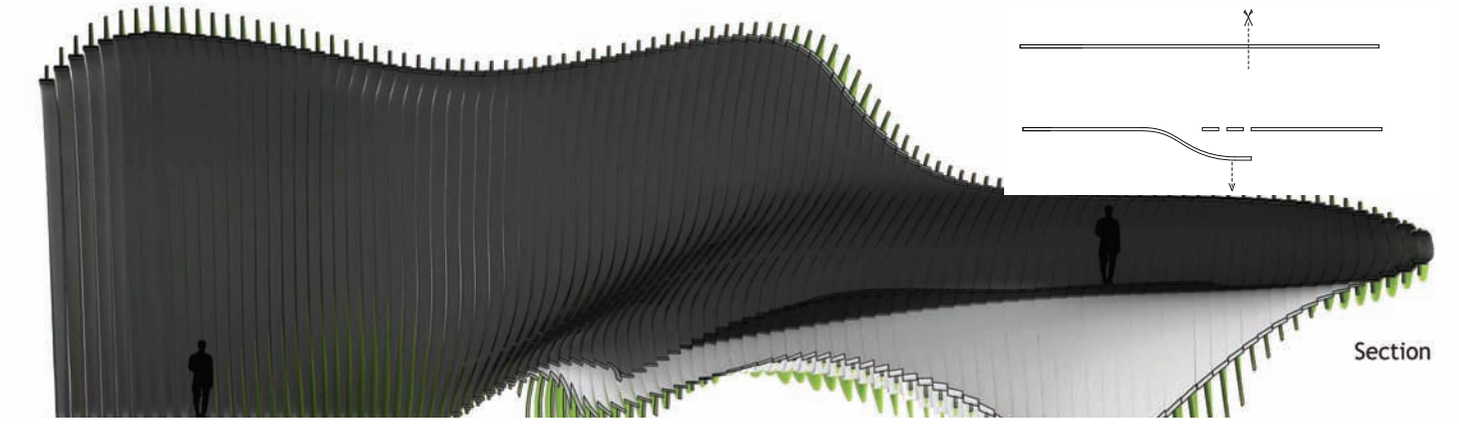
Digital Design Strategies

The overall project could be regarded as an integrative design strategy for refinement of a self supported spatial envelope, but the different project aspects could also be re-deployed individually.
[Contexts II: p.84, p.173]

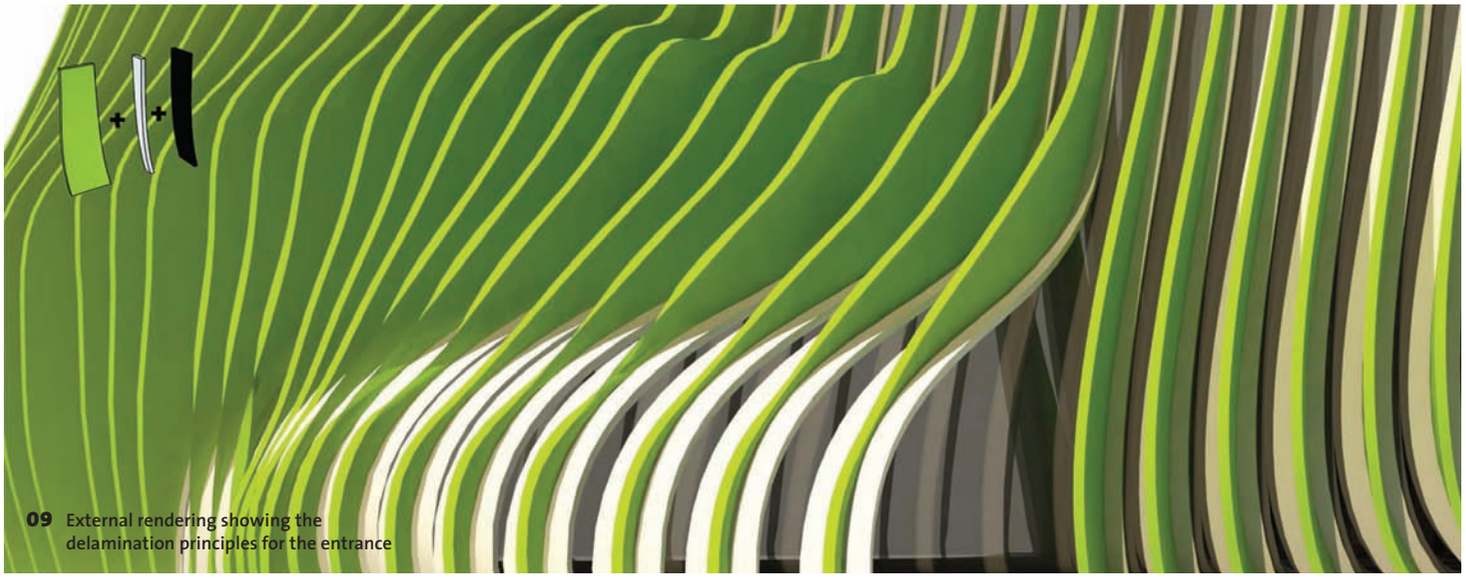
06 Material layers of the pavilion; gray-transparent, white solid, green-structural



07 Plan, with awake space on left side, asleep on right side, and delaminated entrance at bottom

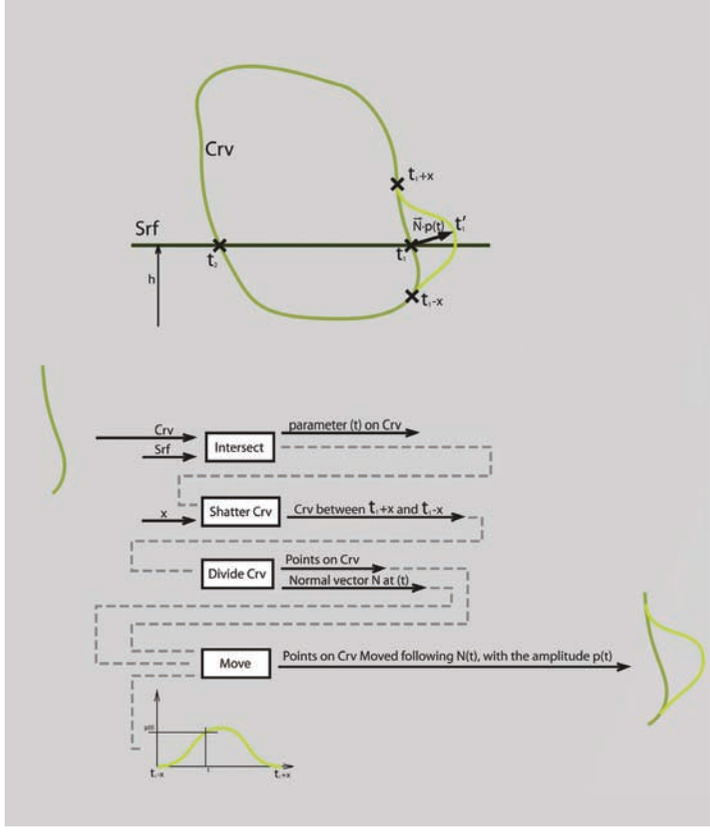


08 Section showing verticality of awake space and horisontality of asleep space

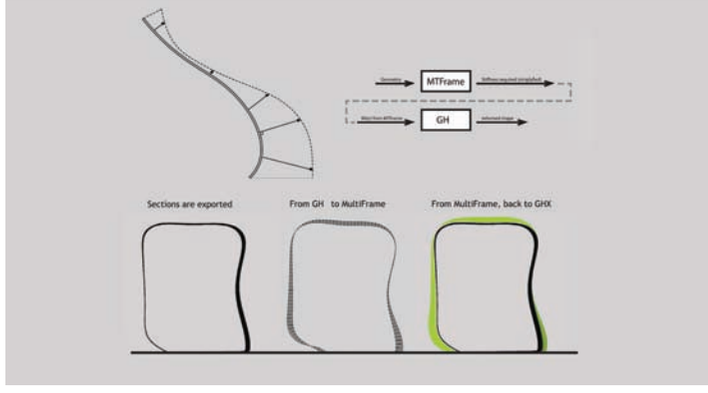


09 External rendering showing the delamination principles for the entrance

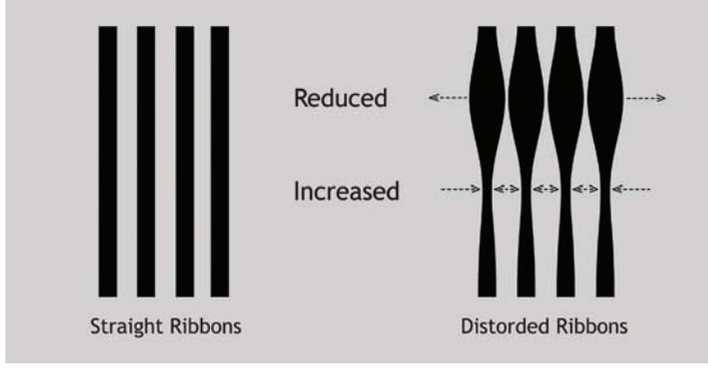
10 External view of structural frames



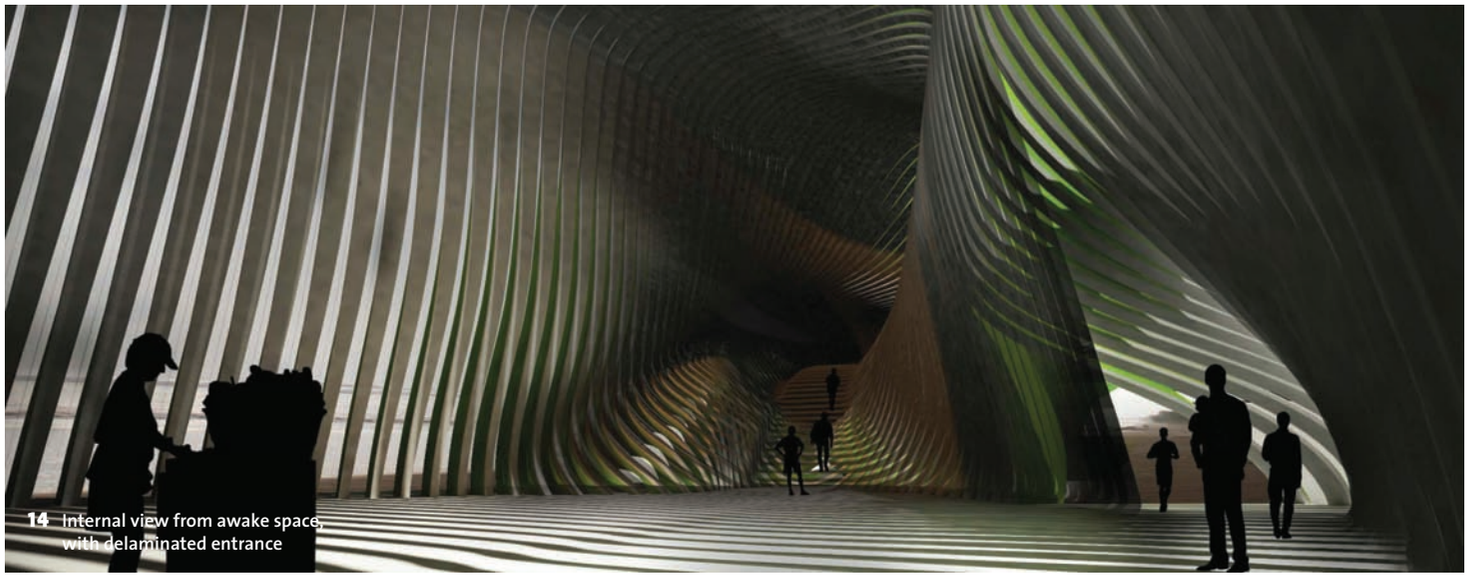
11 Principles for entrance delamination



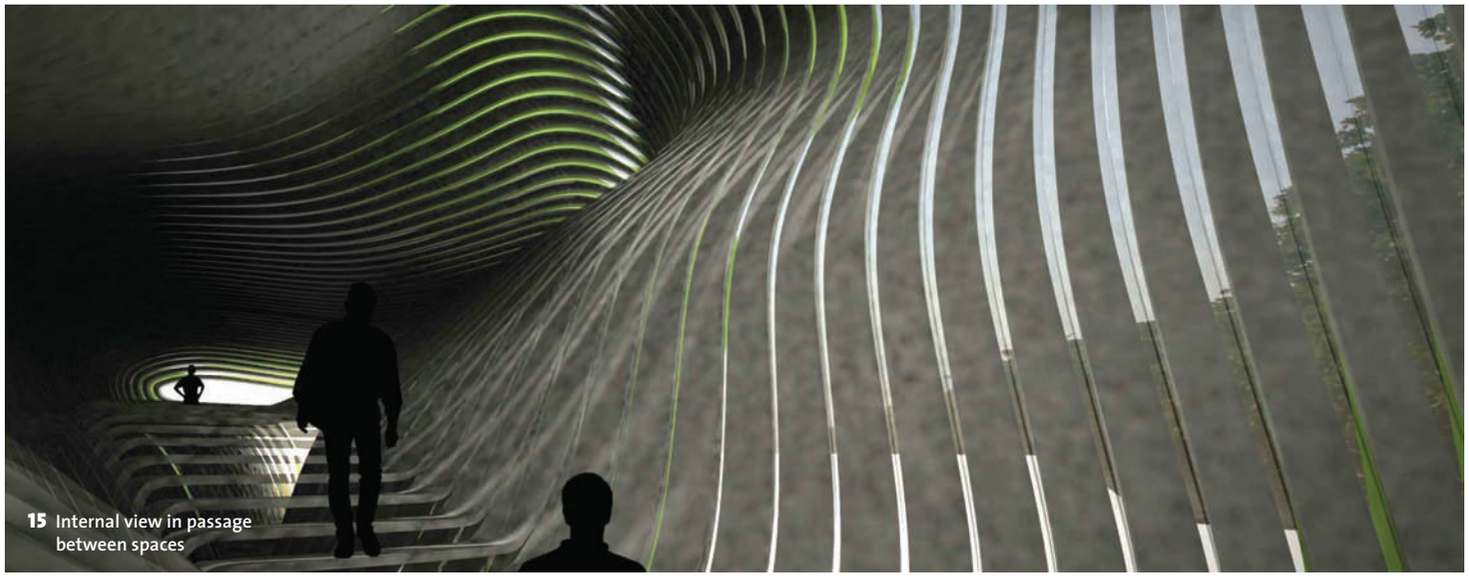
12 Principles for structural optimization



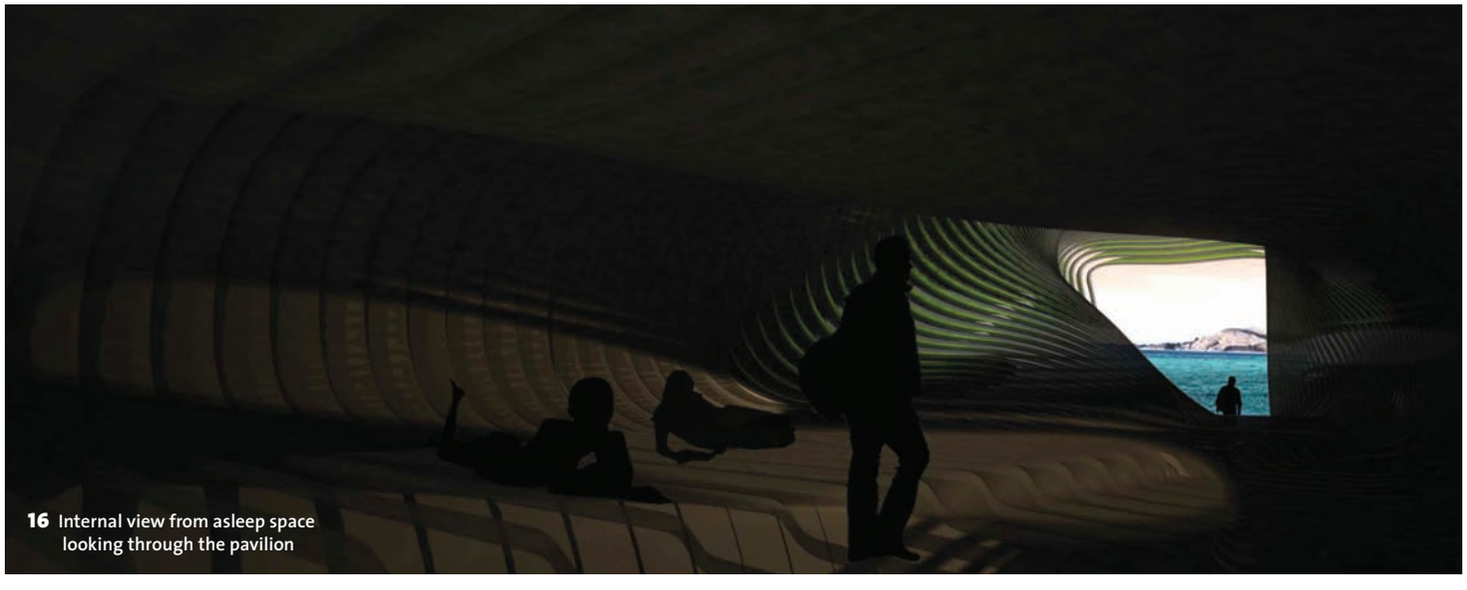
13 Principles for aperture variation



14 Internal view from awake space, with delaminated entrance



15 Internal view in passage between spaces



16 Internal view from asleep space looking through the pavilion

Labyrinth Wall Pavilion

Elsa Wifstrand, student KTH Studio 11, 2010

The 'Labyrinth Wall Pavilion' project, as part of the first semester of the studio, originated in particular spatial configurations and envisioned effects, set as goal in the development of a parametric system that would provide control over an envelope at component level. With a focus on the articulation of daylight and views, as well as a structural solution for fragmented panels, the project was set up as a well defined design problem, in which the expected design outcome was intuitively interpreted, but configured in an explicit way.

Design Narrative

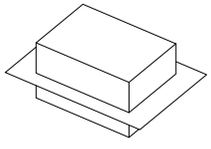
This is the second presented project developed in the primer workshops of KTH studio 11. The intention of the brief was to develop systems that integrated spatial design with structural evaluation, either in an implicit or an explicit way. The architectural challenge was kept simple; the students were asked to design two spaces of different spatial qualities, with a relation to ground, and a vertical transition between them. The student in this case made a very fast assumption of the overall spatial form, and put all emphasis on work at the scale of the components, with the ambition to achieve spatial variance through articulations of the envelope. Two external references were used to set the conditions of the two spaces; a forest canopy filtering daylight and a semi-lit cave [01]. Two spaces of identical dimensions were stacked vertically, one below ground and one above [02], and the borders were planned to be blurred through the use of layered and fragmented partitions [03].

These basic formal principles were the foundation of the development of a parametric system as means to control the articulation of the partitions. The formal principle introduced was one of orthogonal plates, of different forms, proportions, sizes and positions, distributed into different layers. The basic premise that partitions would be planar and orthogonal, allowed each wall, as well as the floor and roof, to be fragmented, and in this way the same parametric model could be employed to generate each of them. In an initial uniformly distributed point grid across a surface, random points were selected as the base for an initial generation of square surfaces [04 a – c]. These were then transformed into rectangles of different size and proportions, again in a random way, and overlapping rectangles were merged into more complex polygon surfaces [04 d + e]. This was repeated for a total of four layers. The parametric model was set up to map the overlap between each adjacent layer, and position structural connecting elements in these areas, as horizontal or vertical plates [04 g + h]. Surfaces intersecting with the ground plane, and selected surfaces below the ground plane, were extruded to create floor plates within the layered envelope, including the staircase, as well as external seating platforms [04 + 05].

Several generations of the system were produced, and evaluated in order to arrive at the final proposal. Important criteria for evaluation included the potential vertical walkways within the layered envelope, the views between the two levels and the transmission of light from the outside into the upper space, and further into the lower space. The evaluation was based on an intuitive understanding in regards to the amount of light, and in the creation of interesting views between outside and the two internal spaces [06 – 09]. Similar principles were employed for the roof and ground floor. The completed system finally integrated all layered partitions for walls, the floor and the roof, and alternate entry routes could be mapped in the design [10].

The design development also integrated basic structural evaluation, in which abstracted versions of the layered and interlocking envelopes were tested for potential deflection [13]. This became important criteria for the decision to flip the direction of structural linking elements between the layers [11]. The use of more complex polygonal surfaces also allowed elements to be connected in several positions, in a way that enabled a very complex topology for the structural system [12]. Certain structural elements needed to be removed in order to provide access into the pavilion at ground level, but these passages also followed the layered logic, and turned into labyrinthine effects [14 + 15].

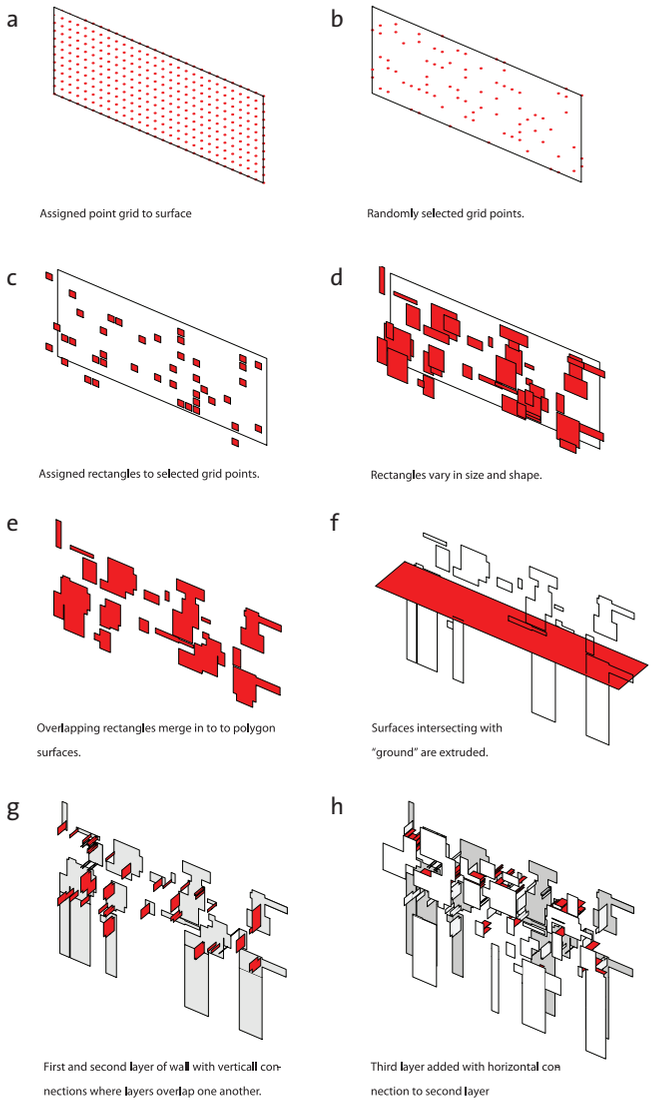
01 External references for spatial conditions; the forest canopy and the semi-lit cav



02 Basic spatial diagram of vertically stacked spaces

03 Diagram of desired light admission into the two spaces

04 Staircase integrated between layers



05 Principles for parametric system and building system

Digital design Techniques

The development of the parametric system was primarily focused on the generative aspects; how to produce a number of variants for a layered surface populated with orthogonal, polygonal panels that overlap. The structural evaluation was conducted as a separate, abstracted analysis. [Contexts II: p.22, p.26]

Architectural Performance

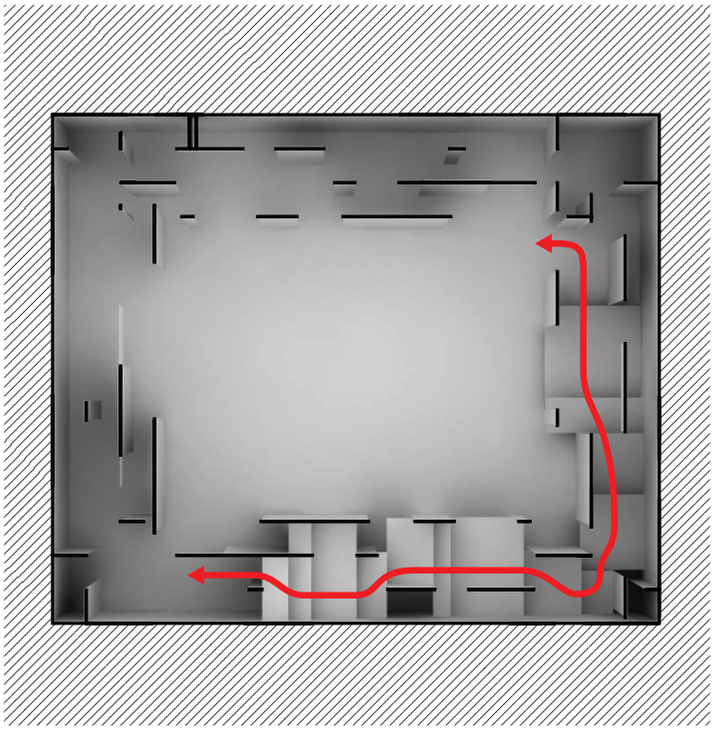
The structural performance was analyzed at a basic level to ensure the principle of assembly was valid and did not infer with the aesthetic ambitions of the project. The spatial effect of based on the analogies of the forest canopy and the semi-lit cave is achieved through the configuration of orthogonal and layered components that also enables yet camouflages the entrances to the pavilion. [Contexts II: p.38, p.39]

Speculative Design Aspects

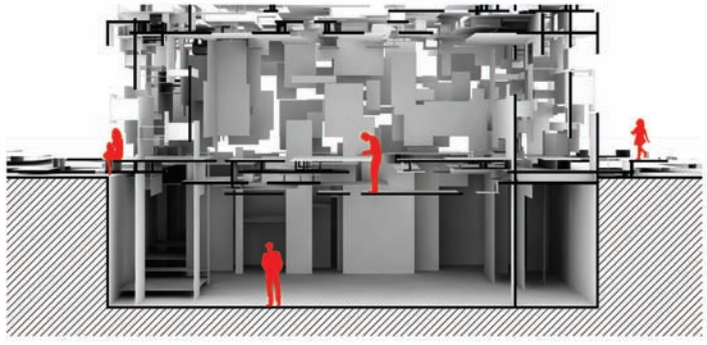
The project was based on the speculative hypothesis that an artificially constructed space can achieve experiential qualities similar to natural conditions, and this set the criteria for the development of parametric systems. [Contexts II: p.60, p.61]

Digital Design Strategies

While the project deals with the complete design of a pavilion, the digital development was primarily focused on the multi-layered envelope. This could be regarded as a strategy deployable in any envelope, provided climatic insulation is not a concern. [Contexts II: p.84, p.173]

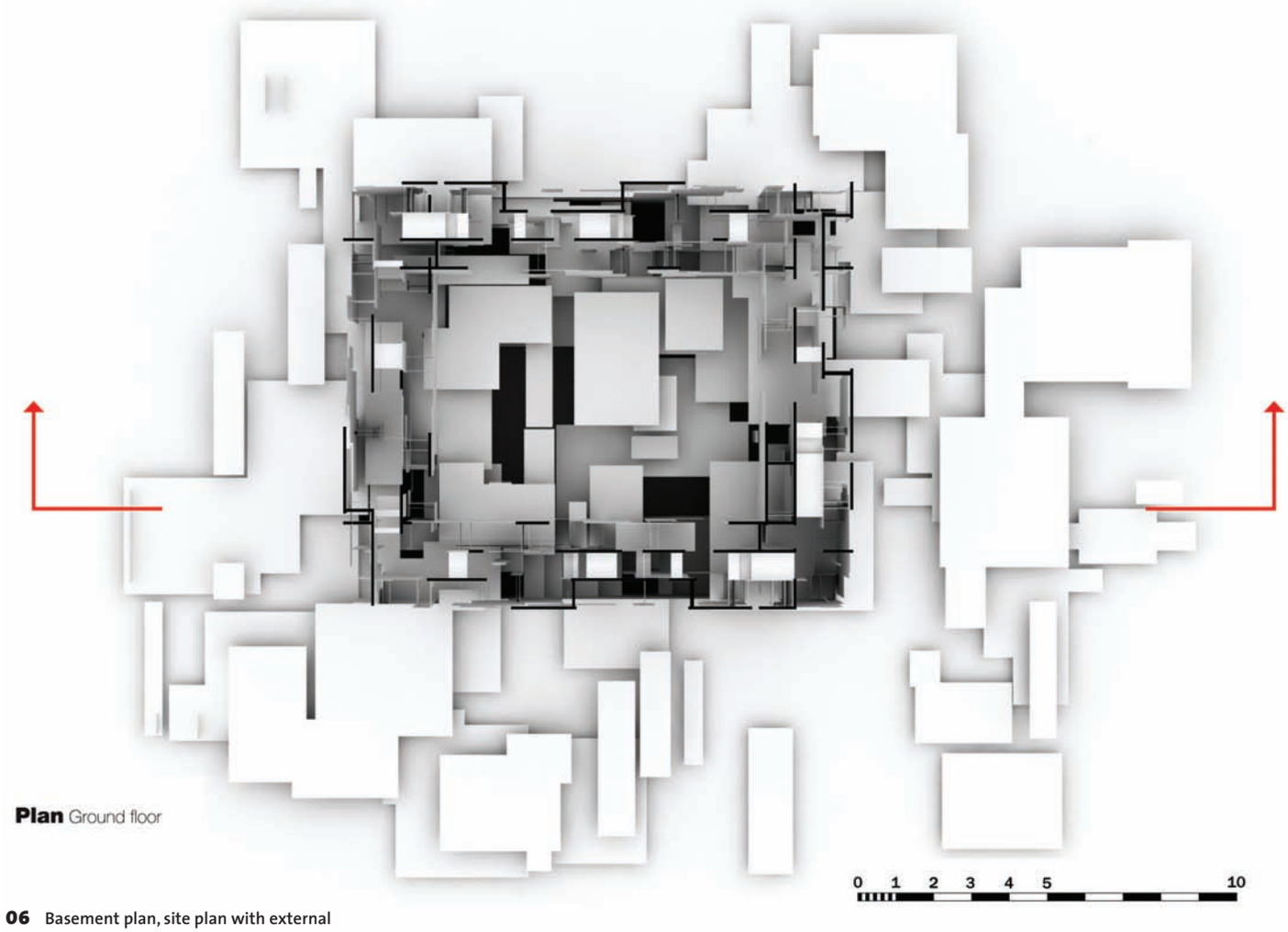


Elevation



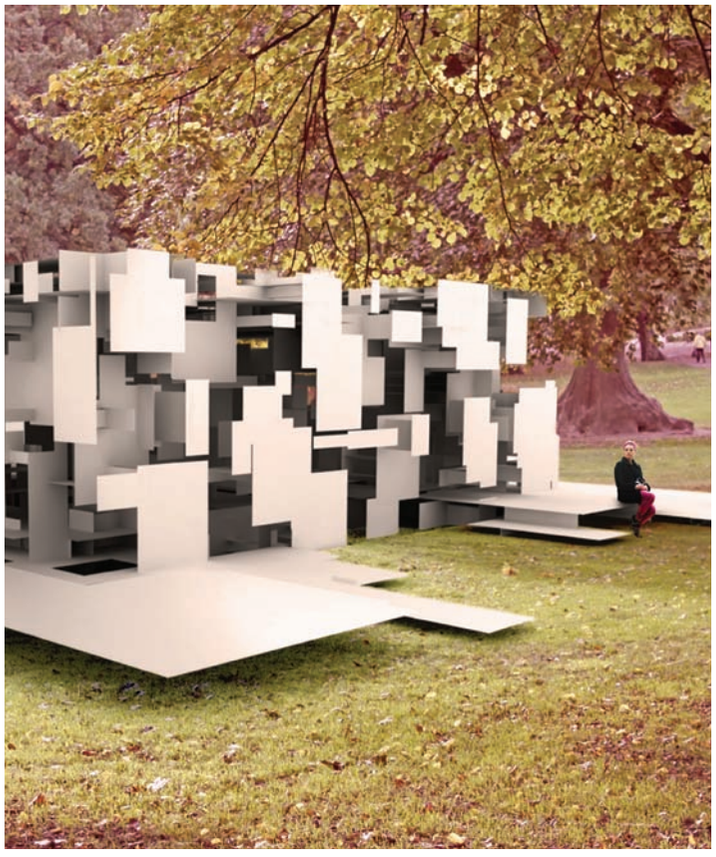
Section

0 1 2 3 4 5 10

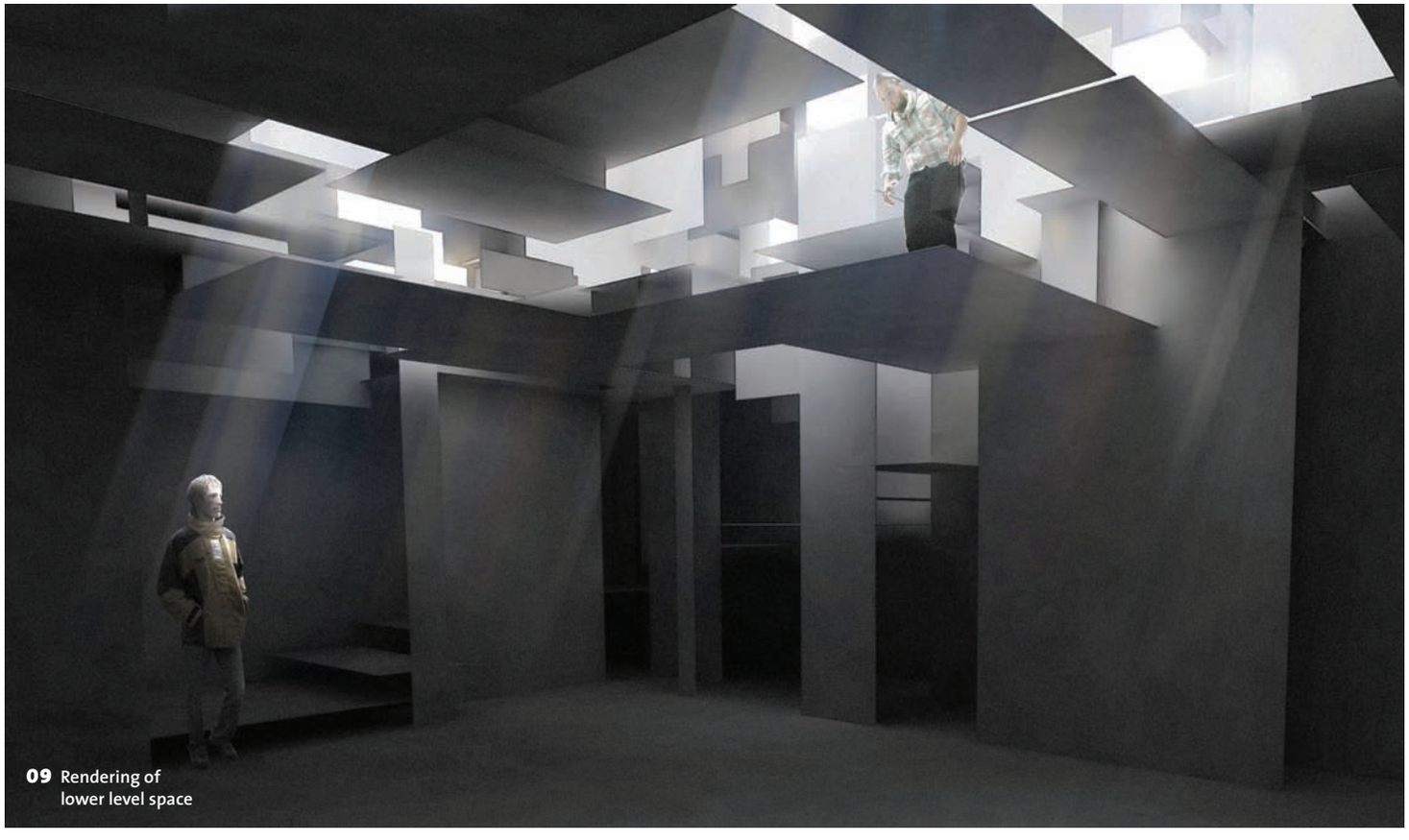


06 Basement plan, site plan with external seating platforms, elevation and section

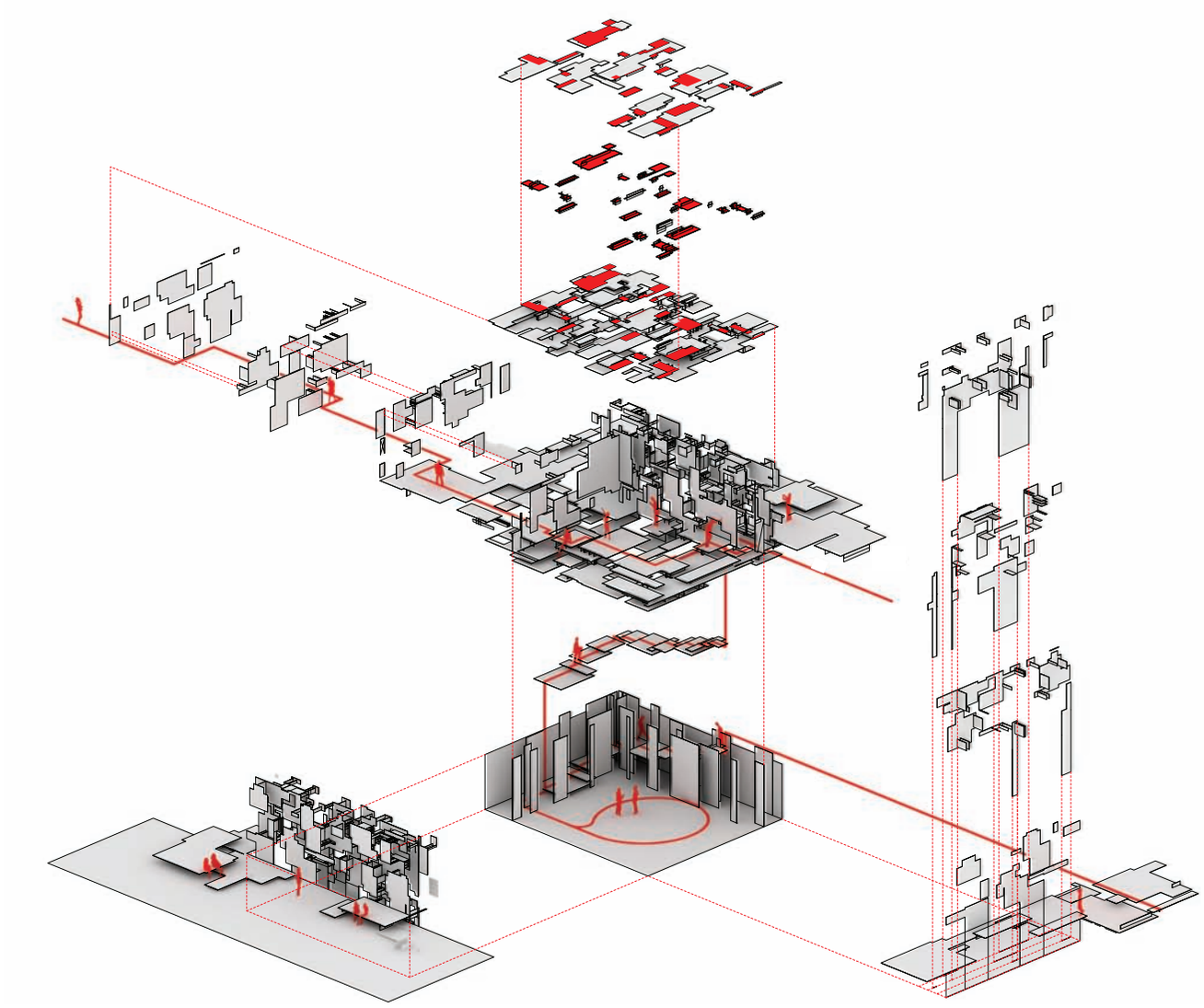
07 Rendering of upper level space



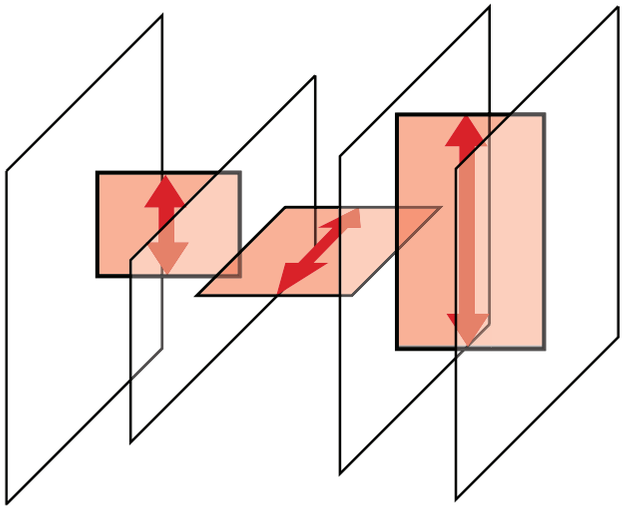
08 Rendering of external view with extending seating platforms



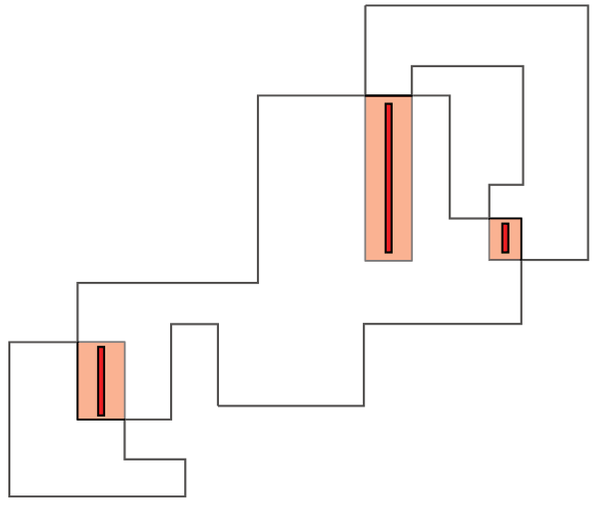
09 Rendering of lower level space



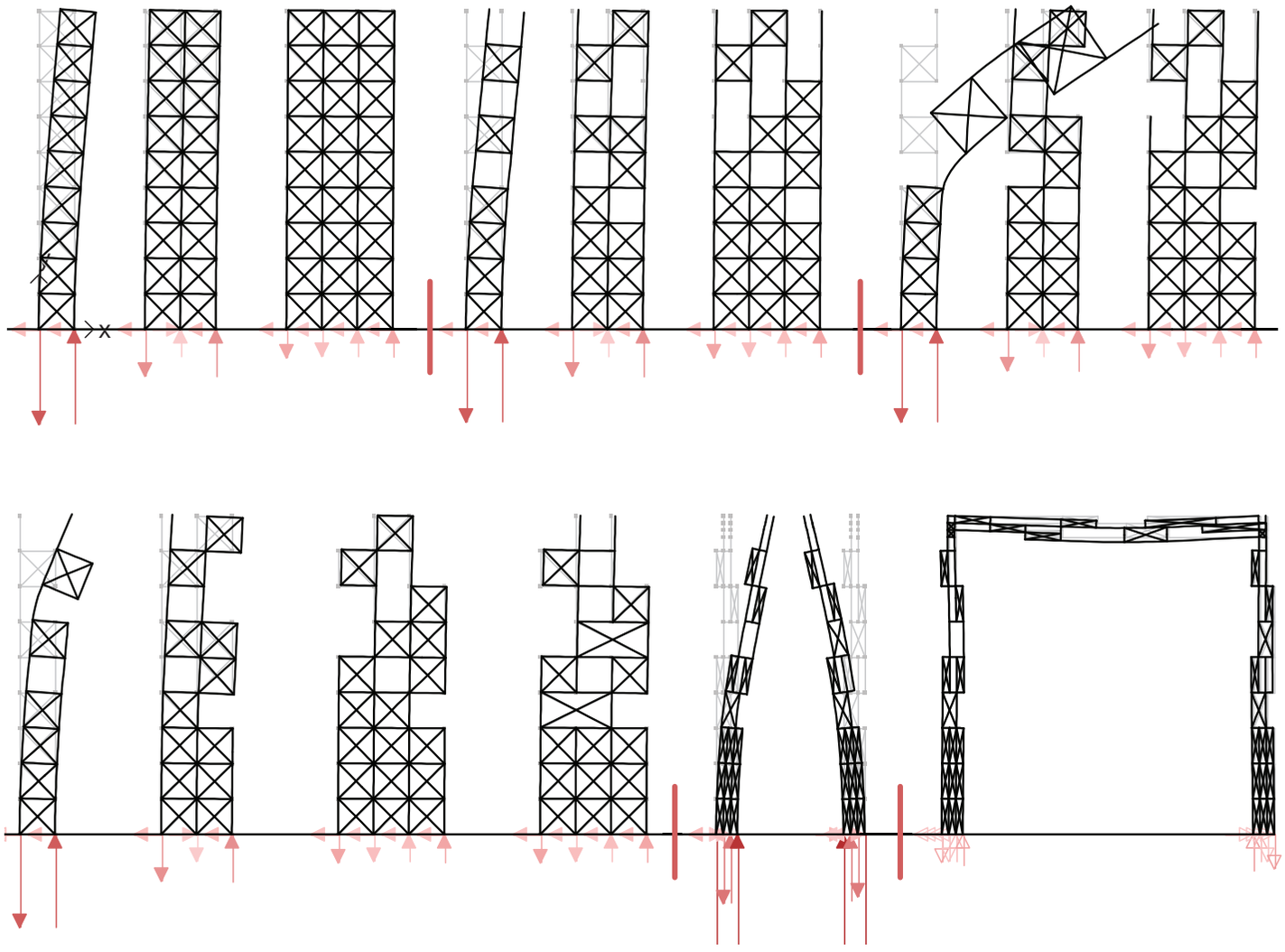
10 Axonometric of integrated system with all layered partitions for walls, floor and roof, the inserted staircase, and potential movement routes in red



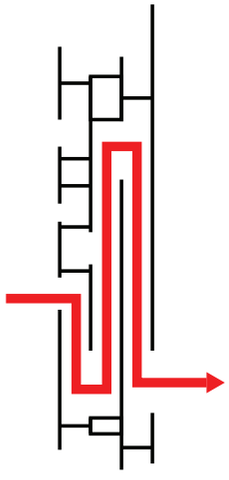
11 Alternating directions of structural linking elements



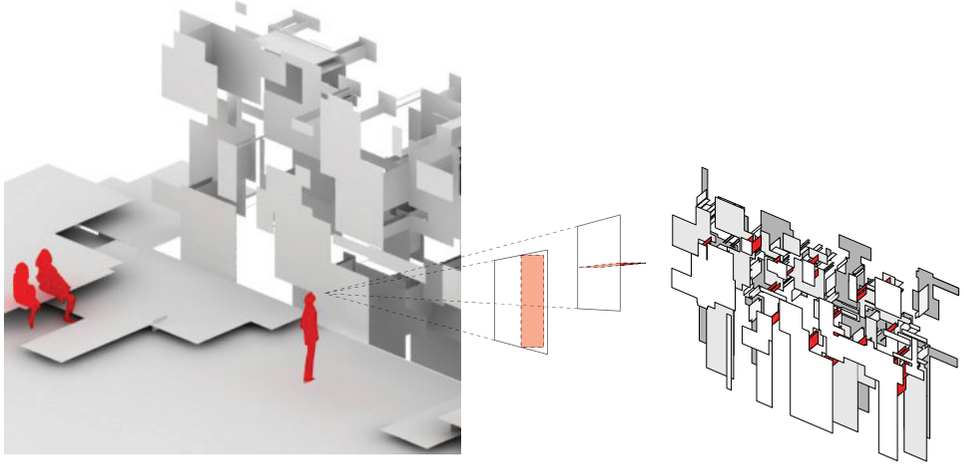
12 Elements overlapping in multiple positions to maximize stability



13 Abstracted analysis of structural deflection, indicating relative number of connecting elements for stability



14 Labyrinthian entry passages



15 Structural linking elements hidden from plain view

Share / Mix / Invite

E Wifstrand, R Alarcon, students KTH Studio 11, 2010

Site specific concerns were introduced as a basis for project development in the second semester of the studio in the form of the Högdalen Energy from waste power plant. With the assigned task of designing a visitors' center, the 'Share / Mix / Invite' project took a starting point in the iterative development of the power plant over a long time with little concern for spatial qualities. The proposed addition used a satellite configuration that protrudes into the facility with minimal impact, yet adds a new identity to the complex, and explored adaptations of similar formal logics, and their structural and architectural performance.

Design Narrative

The project considered the iterative development of the plant since 1970 in order to identify potential future development, and in this way find an adequate position for the new additions [01]. This provided an understanding that a displaced center with connected elevated passageways would be an appropriate way to go ahead, and infrastructural access external and internal to the site pinpointed the specific sites to engage with. [02 + 03]. The terrain south of the facility was also included in the scheme, allowing the development of a looped passage [04].

An important starting point was elevated walkways, and the decision was made to make them as self supported as possible, employing a so called geodesic tube structure that would also allow a freedom in material use for panels, in turn providing unobstructed views of the facility. An initial triangulated scheme was refined through structural analysis, and provided an architectural as well as structural solution [07 + 08 + 14]. The massing of the center itself was based on the features of the terrain as well as potential daylight access [06]. This was further informed by the decision to deploy a similar triangulated principle on the building envelop in two scales, as primary structure and paneling support [05 + 13].

The redeployment of the triangulated truss was an important factor in developing a formal identity, both as viewed externally, and in creating an articulated passage for the visitor. The external expression was further enhanced in the use of color, through screen printed patterns on all panels that would remain white on the inside [13]. The choreographed route from entrance to key viewpoints starts inside the visitor center with a continuous passage into the elevated corridors [06 + 09]. Through the elevated passage visitors can get an overall view of the facility, and gatherings can be made at different locations, as part of a tour [10]. The waste bunker, in which waste is lifted into the furnace, was considered a main attractor, and the passage here transforms into a lecture hall [11 + 12]. The selected geometrical approach of triangulation was while developed, initially as part of the structural passageways, possible to redeploy as an envelope with structural performance. As part of the massing of the main center, this allowed a play between building volume and terrain, while allowing a conventional building to be design within the envelope. Structural optimization was only conducted at a conceptual stage, but further development would have enabled the design of an efficient structural solution in which the general structure of the building could have been minimized.

Digital design Techniques

Parametrical modeling was primarily used at a conceptual level, to define the principles of the geodesic tube. Subsequent development was conducted as direct modeling, informed by previous findings. [Contexts II: p.22, p.26]

Architectural Performance

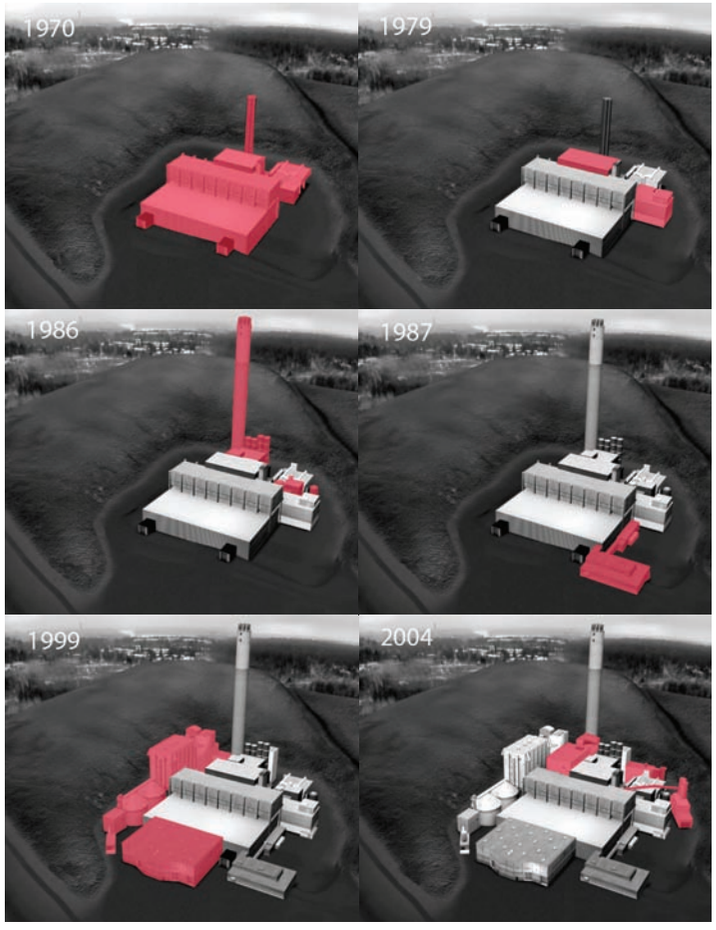
The geometrical principle of the geodesic tube enables structural evaluation and provides a coherent architectural identity throughout the interior spaces, filtering the views of the existing power plant. The overall objective is to articulate and dramatize the walk through the facility, with key points of attraction being the activities in the plant itself. [Contexts II: p.38, p.39]

Speculative Design Aspects

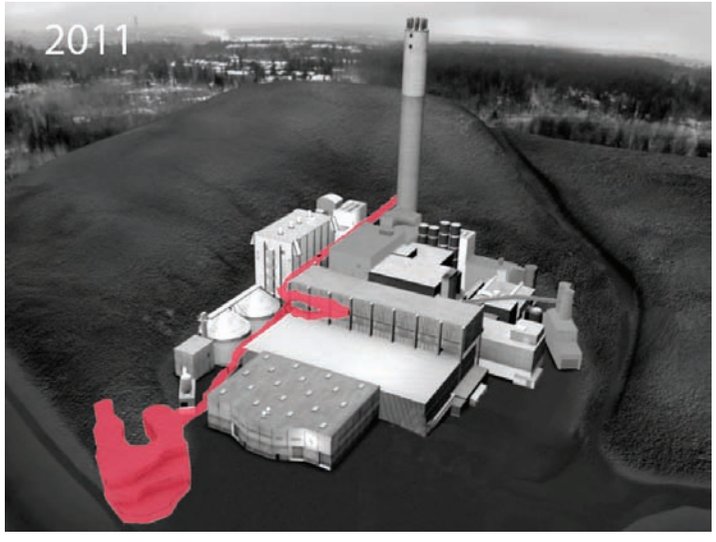
The project extrapolates from the previous development of the power plant (further informed by interviews with current staff) in order to situate the new proposal. [Contexts II: p.60]

Digital Design Strategies

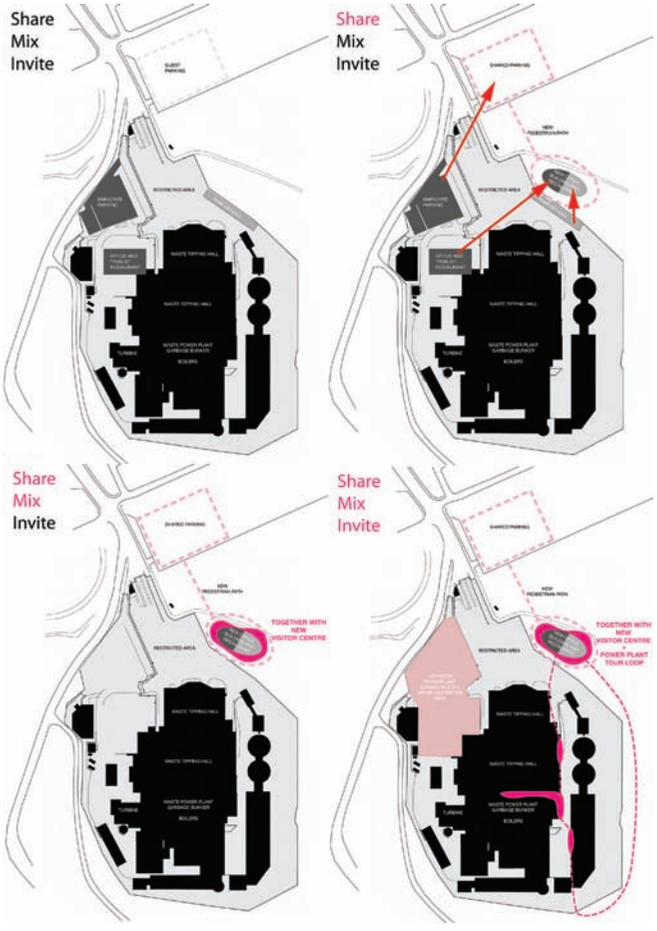
With a base in the parametric development of the geodesic tubes, a strategy for a self supported envelop, this project also includes additional digital design development in which alternate envelopes are linked to massing. [Contexts II: p.84, p.174]



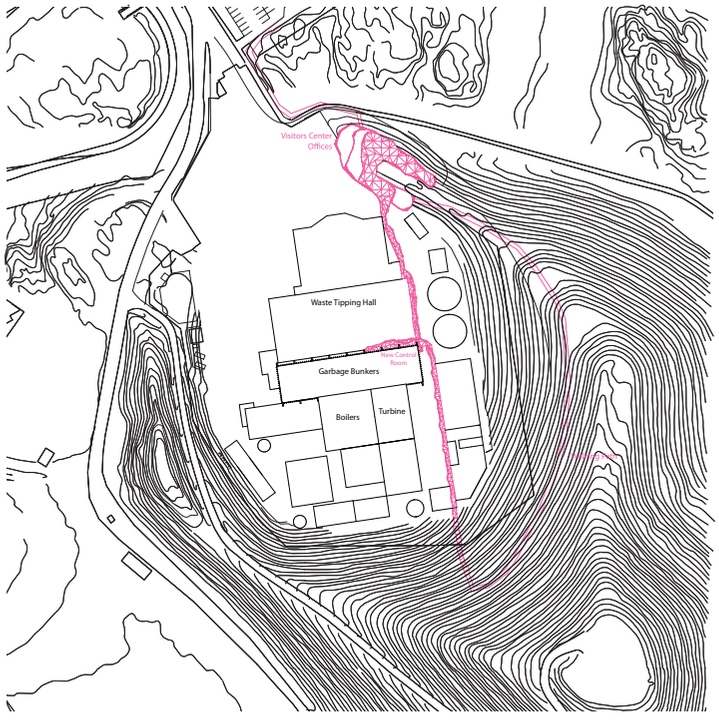
01 The extension of Högdalenverket over a period of 40 years



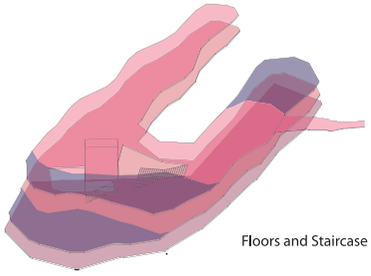
02 The extension proposed in the project



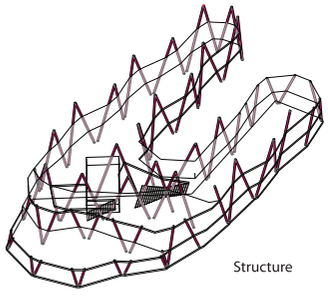
03 Programmatic principles for site use and new building



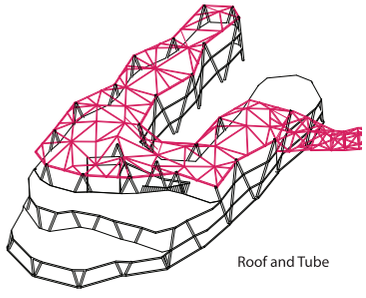
04 Siteplan with extensions in pink



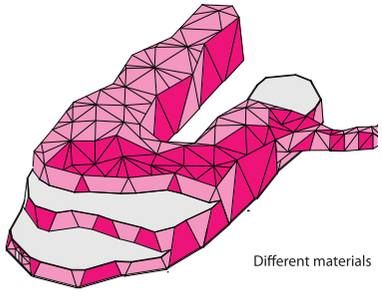
Floors and Staircase



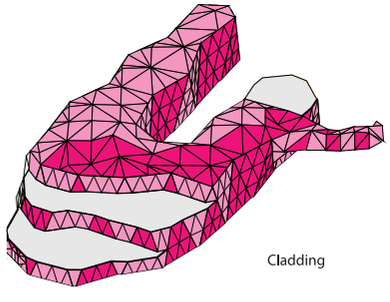
Structure



Roof and Tube

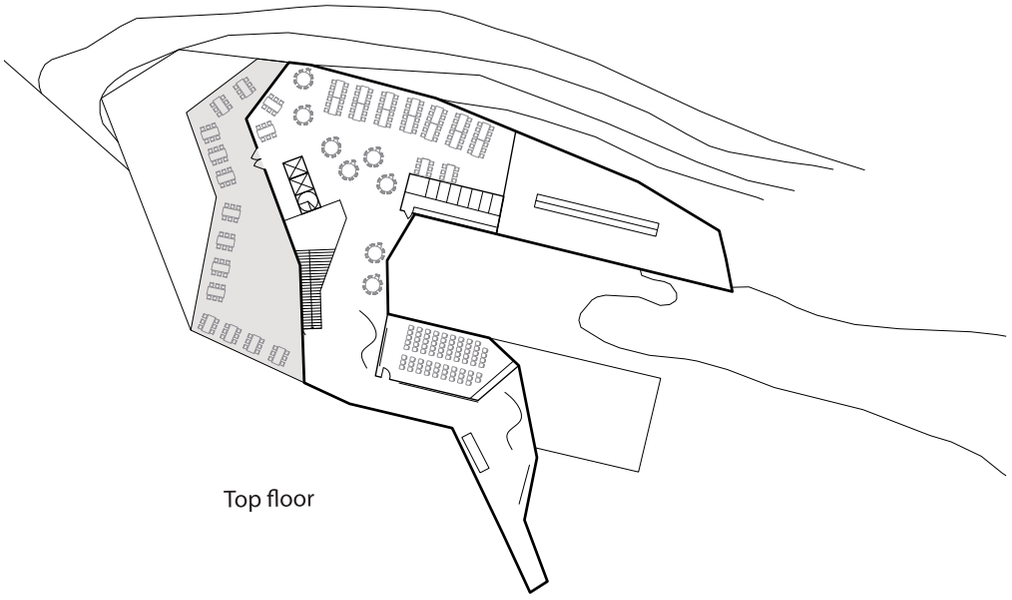


Different materials

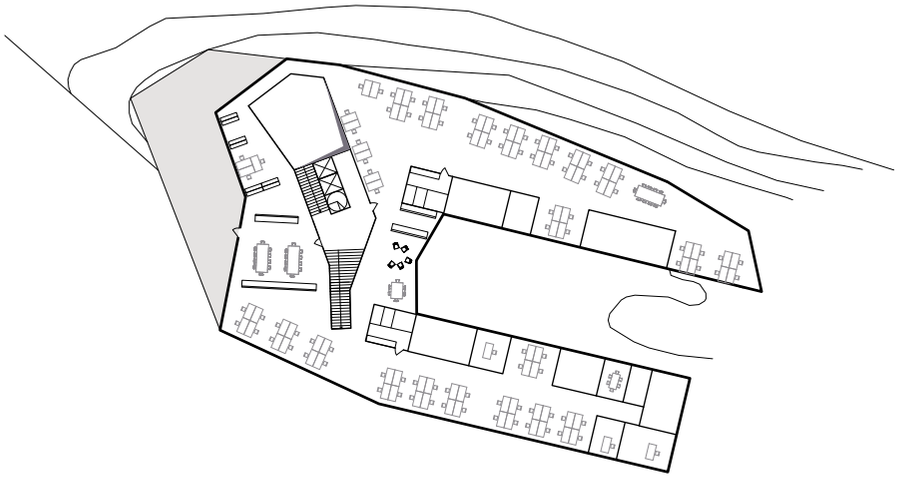


Cladding

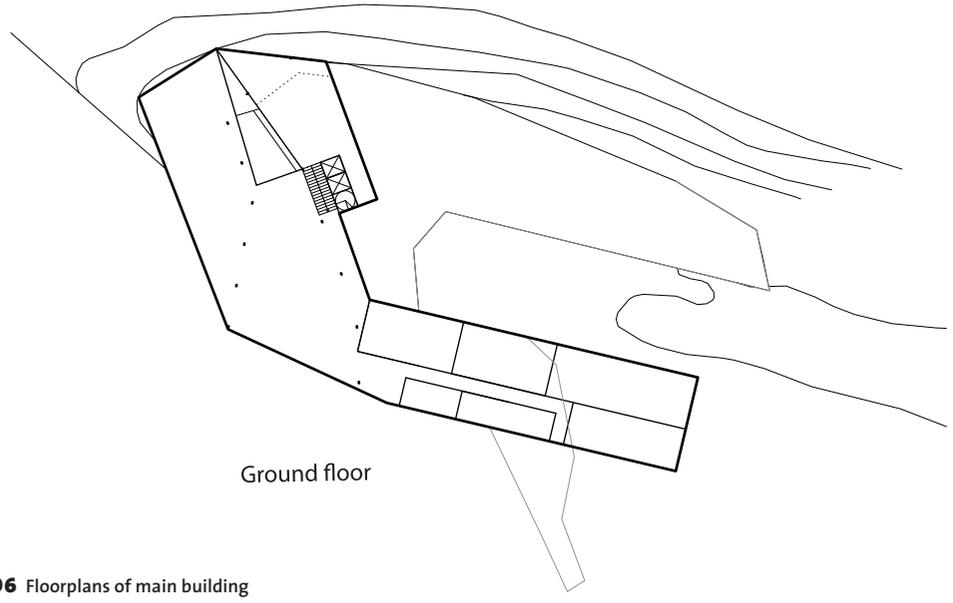
05 The different structural parts of the main building



Top floor

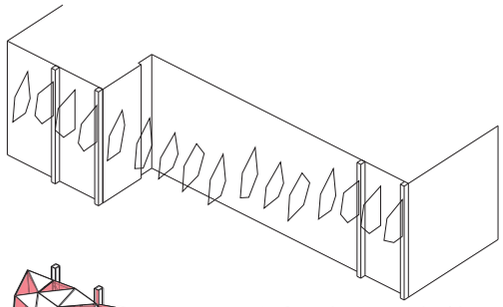


Offices floor

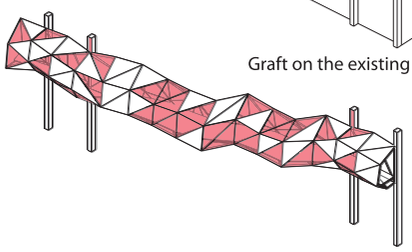


Ground floor

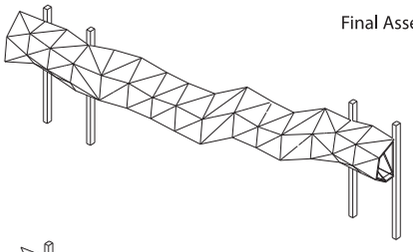
06 Floorplans of main building



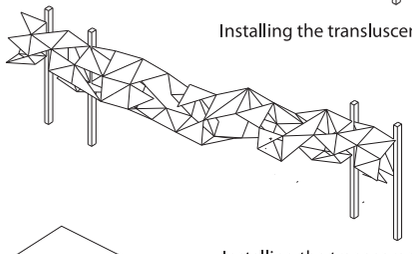
Graft on the existing building



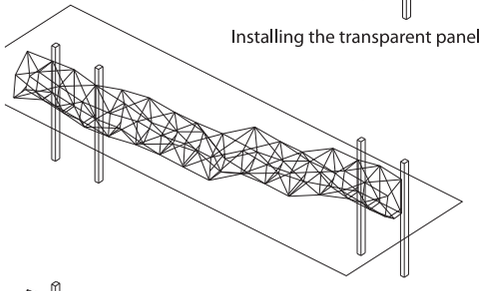
Final Assemblage



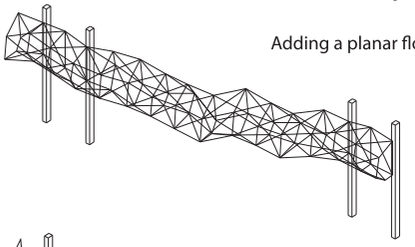
Installing the transluscent panels



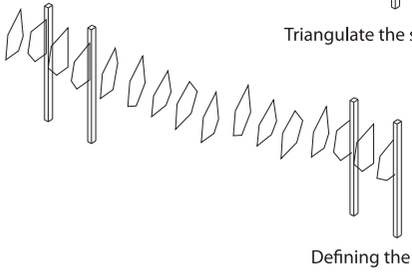
Installing the transparent panels



Adding a planar floor level

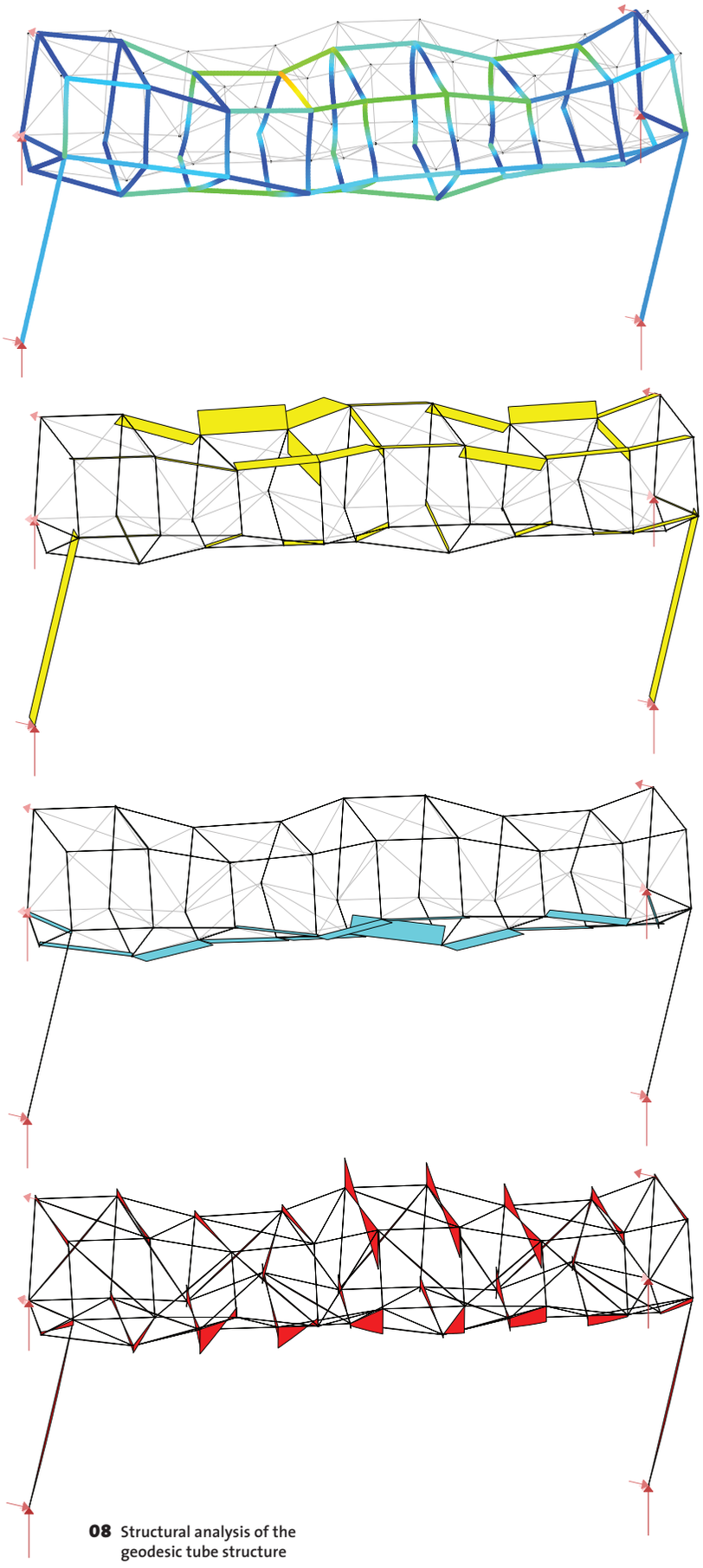


Triangulate the structure

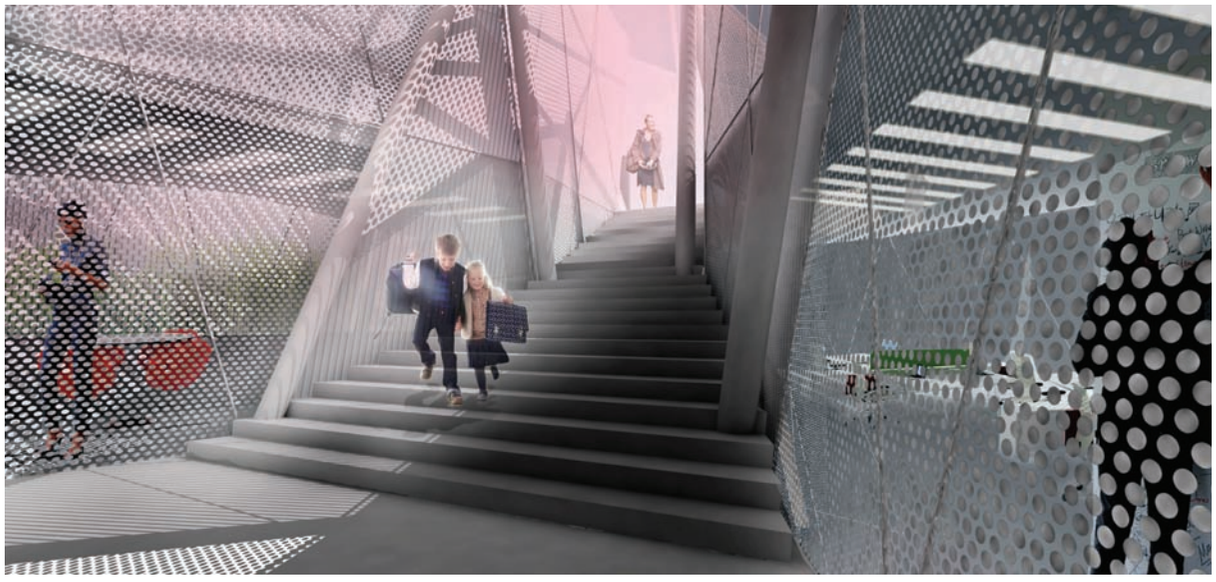


Defining the sections

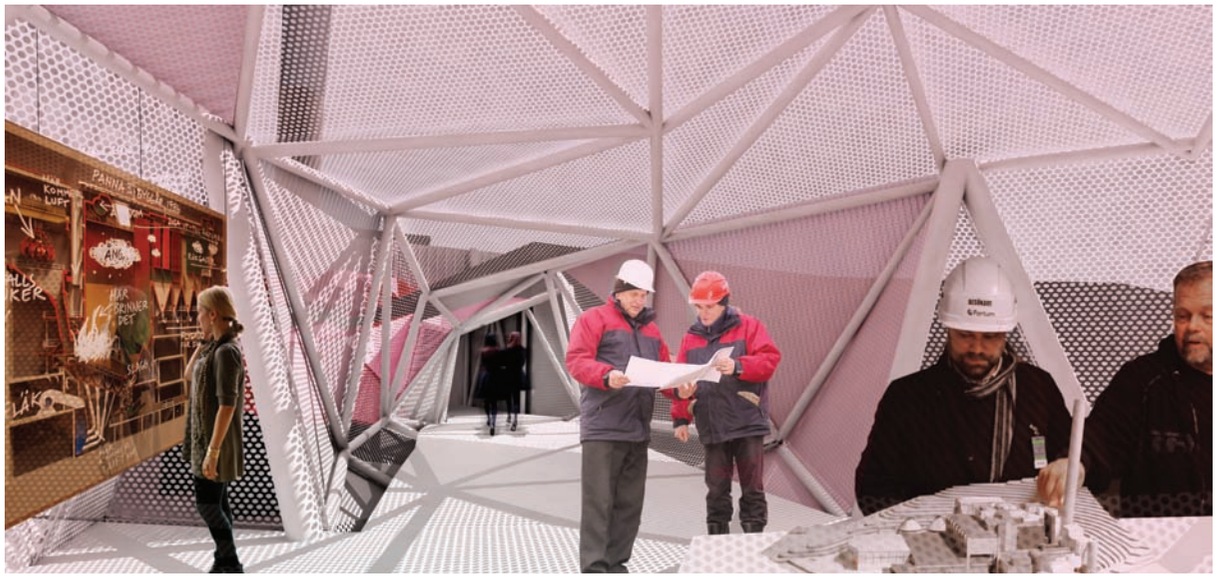
07 The design steps for the geodesic tube



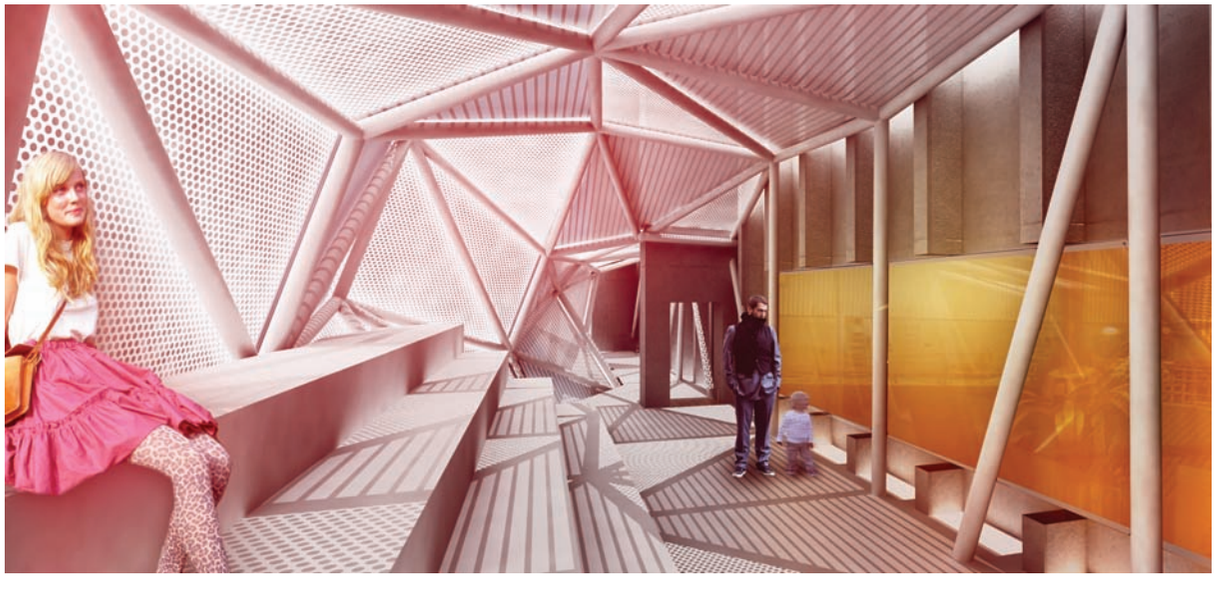
08 Structural analysis of the geodesic tube structure



09 Main Building Staircase: Rendered view from the Office Floor

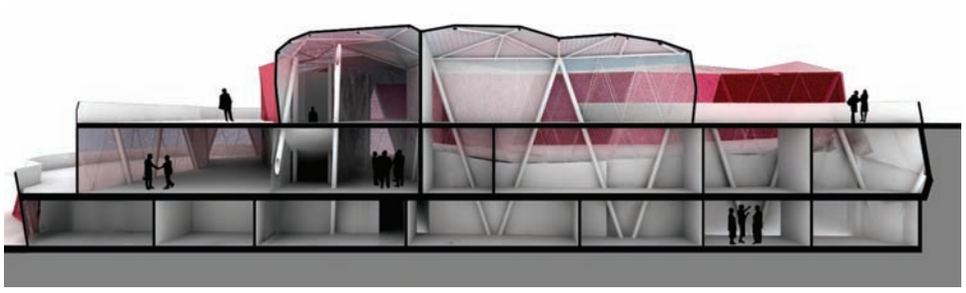


10 Rendered view from the main building to the tube

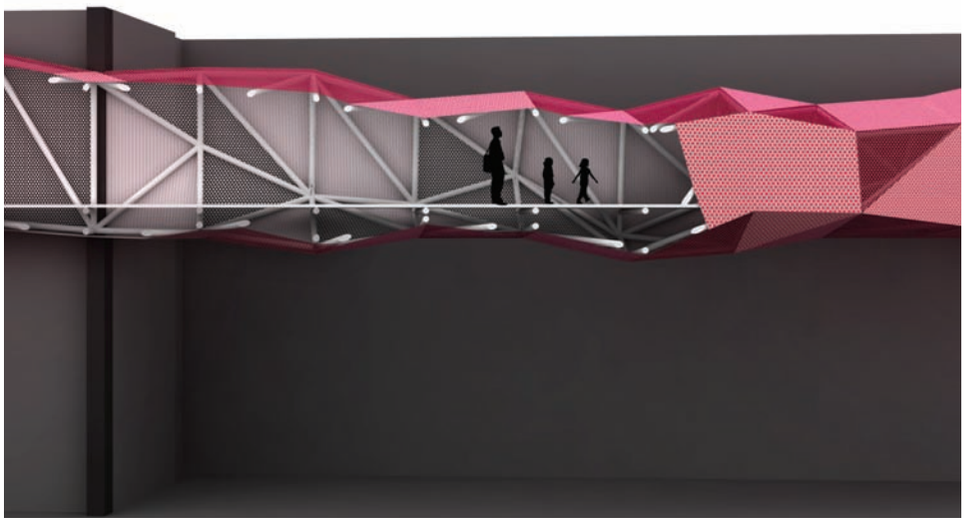


11 Rendered view inside the lecture space

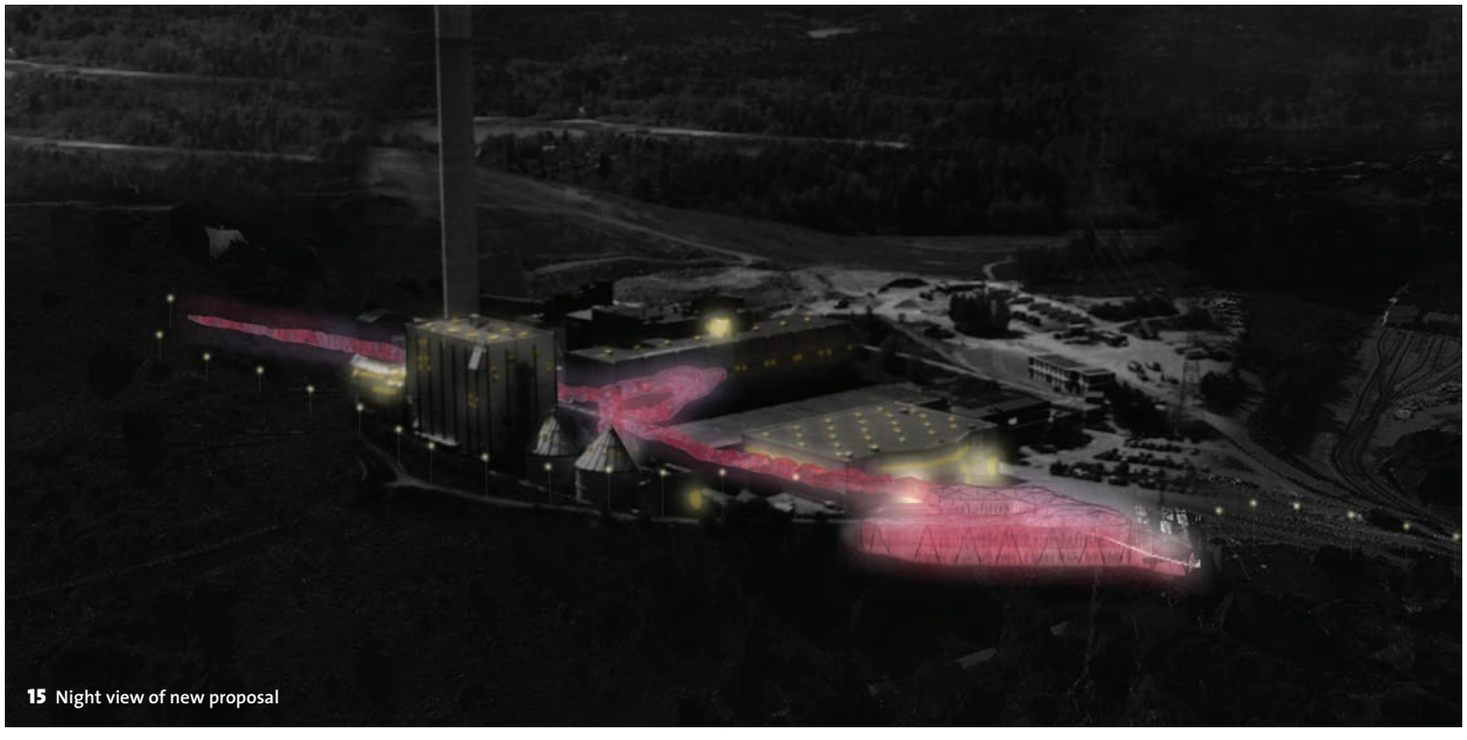
12 Section through lecture space, also showing exterior and interior facade colors



13 Main building section



14 Partial section through tube



15 Night view of new proposal

Adjust[ed] Folding

G Stouck, E Esra Top, students KTH Studio 11, 2010

This second project with the given brief of the Högdalen Energy from waste facility, the 'Adjust[ed] Folding' project employed an plug-in approach. A new formal principle used in all parts of the project added new identity, and provided opportunities for an integrated approach in regards to digital design models and performative studies. Triangulation was here employed for self-supported cladding, rather than a separate structural system.

Design narrative

Using the existing structure of the facility to organize and support the new proposal, this project started in the identification of key points of interests for a visitor, programmatic relations and formal concepts [1]. The main formal design strategy, based on the metaphor of crumbled paper, later refined to folded surfaces, was developed in direct response to the chaotic assembly of the power plant [03]. The massing of the facility and the need for clear passage further gave a massing principle, of folding planes semi-attached to the existing structure [04]. In the first studies, paper was simply draped around the different elements of a mock-up model [11]. The move towards a more defined folding principle, facilitated through triangulation of cardboard, allowed a more precise relation to the existing structures [12]. The concept was also informed by programmatic needs; such as the semi-enclosed exterior space, the elevated walkway, the foyer, the lecture room and exhibition spaces, in which the sheet-like quality either provides surface to move on, shelter from outside, or framed views [18 + 20 – 23].

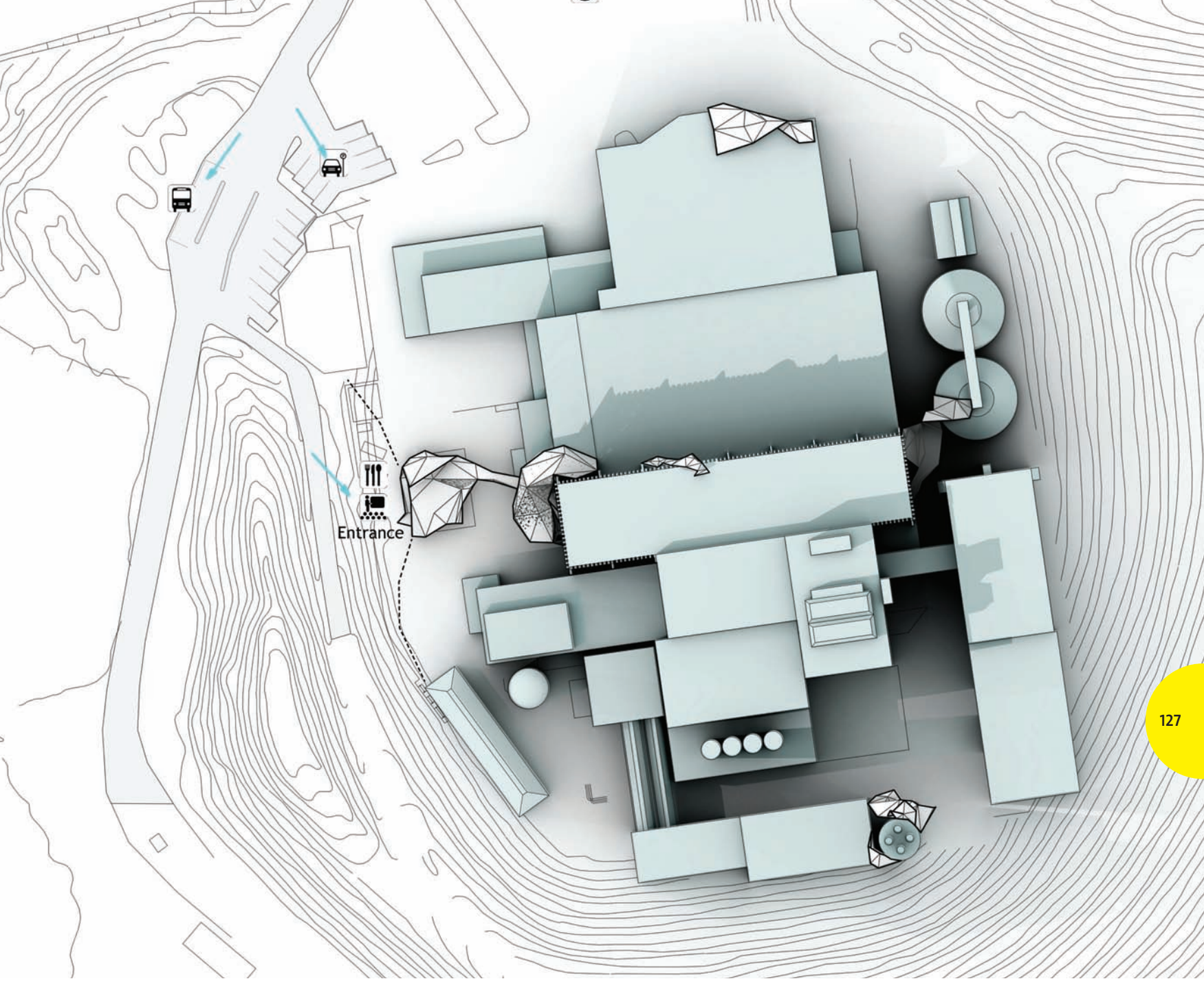
While the basic principle of this folding surface could first be studied in section [04], the spatial characteristics could only be further developed through a parametrical system of triangular surfaces, controlled by shifting the control points of each triangle [05]. The main principle for the configuration of this complex system of triangular surfaces was the manual manipulation of points, allowing an intuitive formation of spaces as needed and appropriate relation to existing buildings. An additional concern was local climate and day light conditions. Using environmental performance software, a climate analysis over the year provided insight on adaptive thermal requirements for the different areas of the centre, and the equivalent daylight study provided further insight on the location of the centre in regards to over shadowing from the facility and the nearby land fill hill [01 + 06]. Once the massing/folding model was set-up, it was also processed to evaluate light exposure on the differently angled surfaces [07], which in combination with definitions on how much light particular spaces would require formed the basis for refined design decision regarding apertures and exact positioning of panel elements. By using evolutionary functions inherent to the parametric design software [09], the design could be refined in two main modes. The amounts of apertures could be varied within a single surface, providing different amounts of direct light in a single space [08]. The overall form could be adjusted to alter the amount of light coming in through larger openings, employed for the semi-covered outdoor space near the entry point of the facility
[09 + 10].

The design exploration in digital parametric models were paralleled with physical models; the initial conceptual crumbled paper model explored general massing and how surfaces could be topologically connected to achieve spaces and passageways [11], and the more refined folded model produced by laser cutter from the digital file, could better evaluate and understand spatial qualities and general structural capacity [12]. The overall design depends on structural stability of the individual triangular panels, defined as semi- monocoque elements. The triangle edges were designed as main structural elements, subdivided for interior bracing and with a smaller scale waffle structure that would overcome any shear forces – in effect turning each panel into a plate [13]. The waffle system set the restrictions for smaller apertures in terms of location and light admission over the seasons [14]. Each panel could have a unique composition, to meet the particular requirements in regards to visual, thermal and acoustic comfort as well as structural capacity [15 – 17]. In a further developed model, relations between structural need and panel structural depth as well as internal subdivisions for structure and aperture could have been set, providing a parametric model in which intuitive formation of spaces could give immediate feedback on performance, and automatic generation of key shading elements and aperture design.

The visitor centre is located inside the pockets of space created from the twisting and folding plate structure, which also provides passage over important transportation routes [20]. The formal strategies also give particular spatial qualities; no space is completely enclosed and open ends are either clad with glass or use the existing facility as partition, no space is generic or neutral, the geometry provides a multitude of formal variants and local conditions [18 + 20 + 23]. Additional application beyond the main visitors' center supports the transformation of identity, and adds additional functions such as a viewing platform [19 + 22].

Digital design Techniques

Physical models were employed in the development of the initial formal concept, and subsequent triangulated surface approach allowed a point based parametric model. Iterative and automated feedback loops employed a parametric model linked to daylight analysis software. [Contexts II: p.22, p.27]



01 The site — Högdalen Energy From Waste facility, with the proposed addition

Architectural Performance

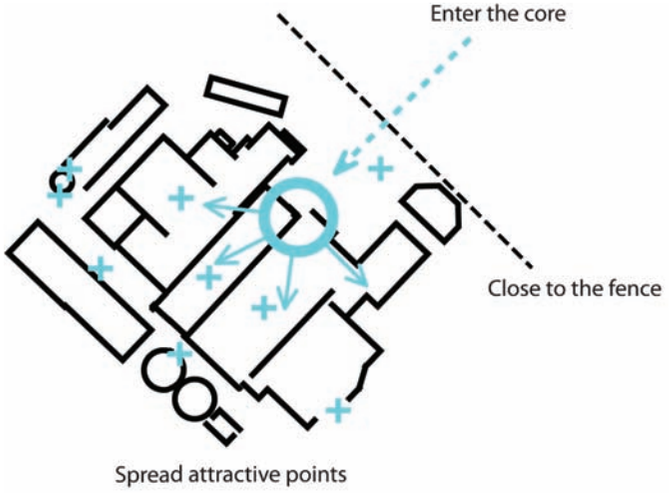
The structural performance relied on the geometrical principle of folding and triangulation, which also enabled basic daylight analysis. Its architectural performance both brings a coherent expression to the addition, and regulates the spatial variations in the interiors. [Contexts II: p.38, p.39]

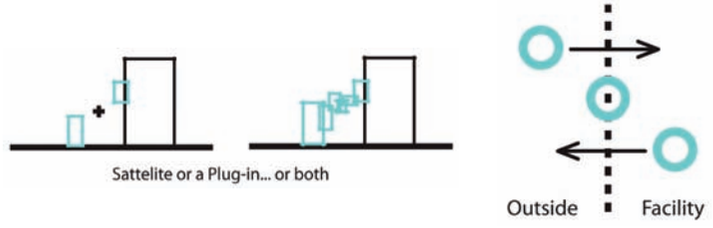
Speculative Design Aspects

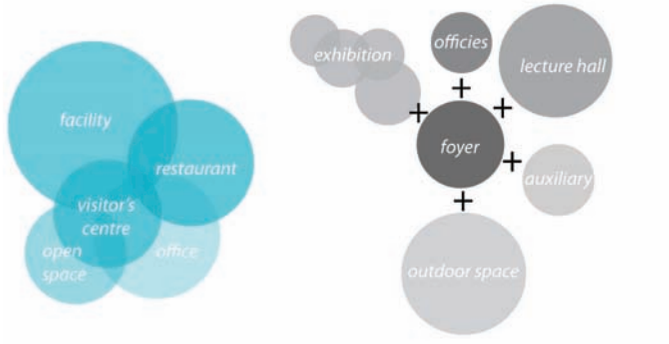
The speculative approach beyond compound design and analysis models, could be identified in the performative aspects of the tilted plane, in terms of experiential effect. [Contexts II: p.60, p.61]

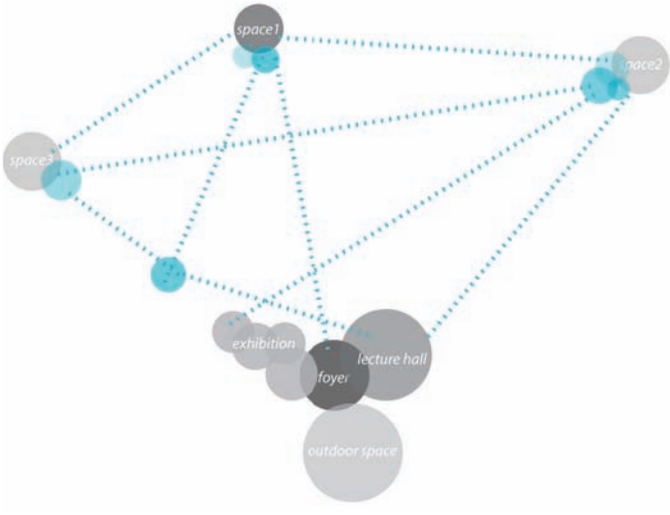
Digital Design Strategies

The folded and triangulated formal principle was the basis for several project aspects, such as massing, envelope and spatial organization, as well as several types of engagement, such as daylight feedback to the design model and fabrication principles. [Contexts II: p.84, p.174]

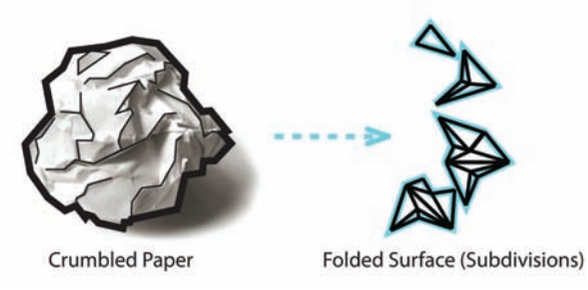




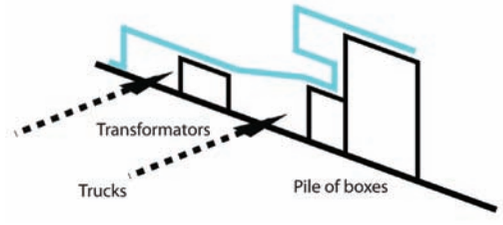




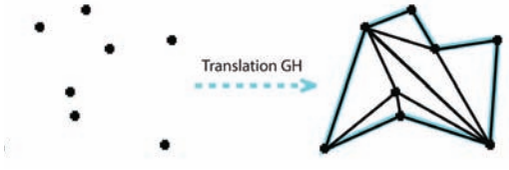
02 Important factors for the design



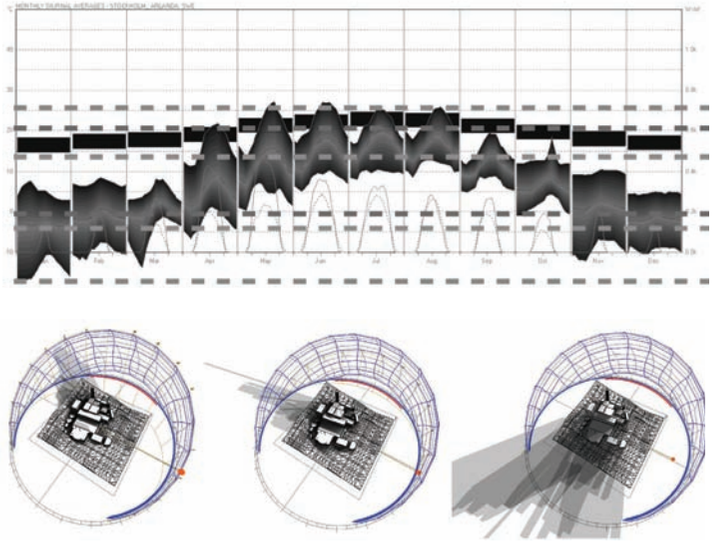
03 Formal concepts



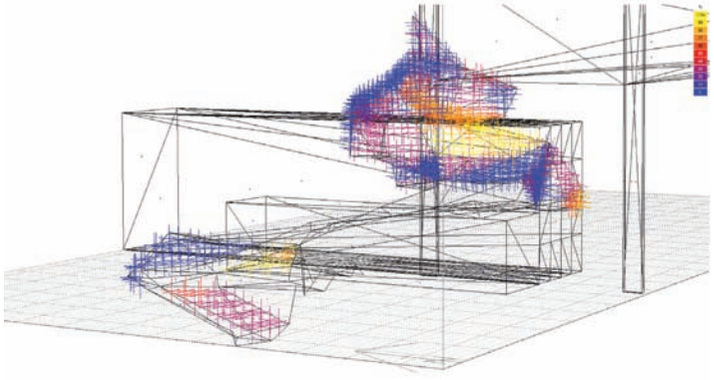
04 Massing and interaction with existing building



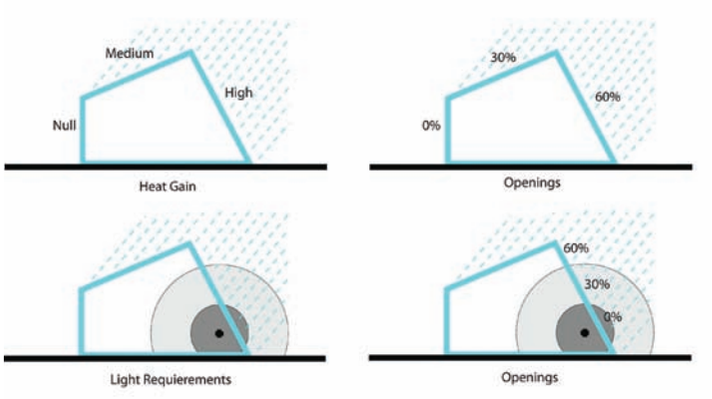
05 Parametric principles for geometry



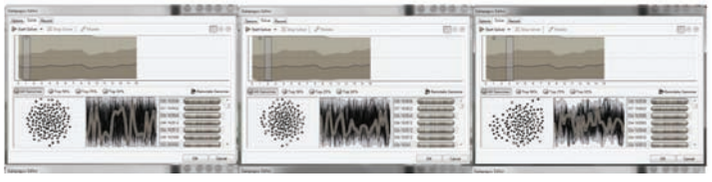
06 Local climate and daylight analysis



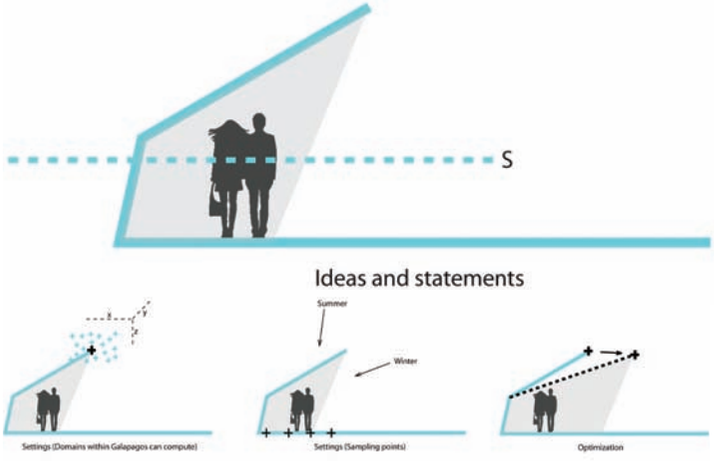
07 Environmental data analysis in Ecotect



08 Decisions on light requirements

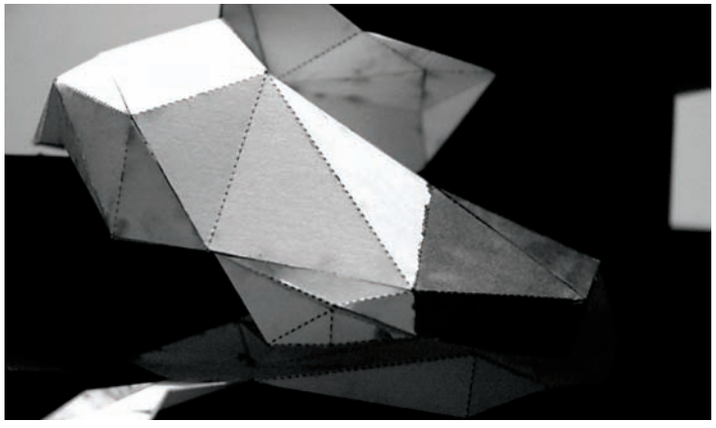


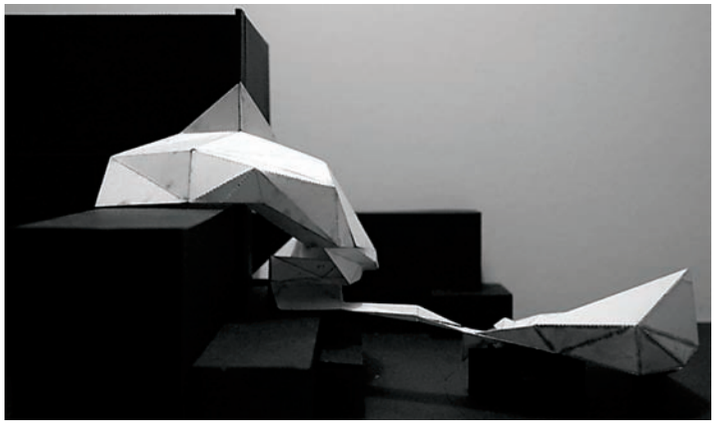
09 Evolutionary solver for shape optiomization



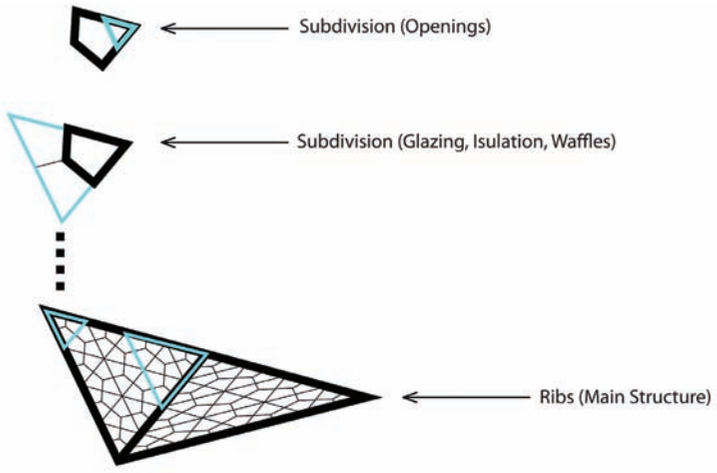
10 Sampling points and domain of configuration

11 Conceptual form and massing model



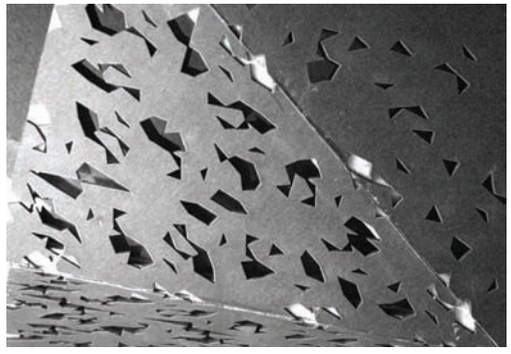


12 Refined and triangulated form and massing

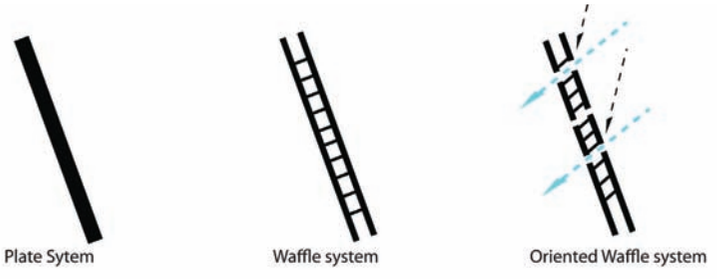


13 Internal geometry of panel

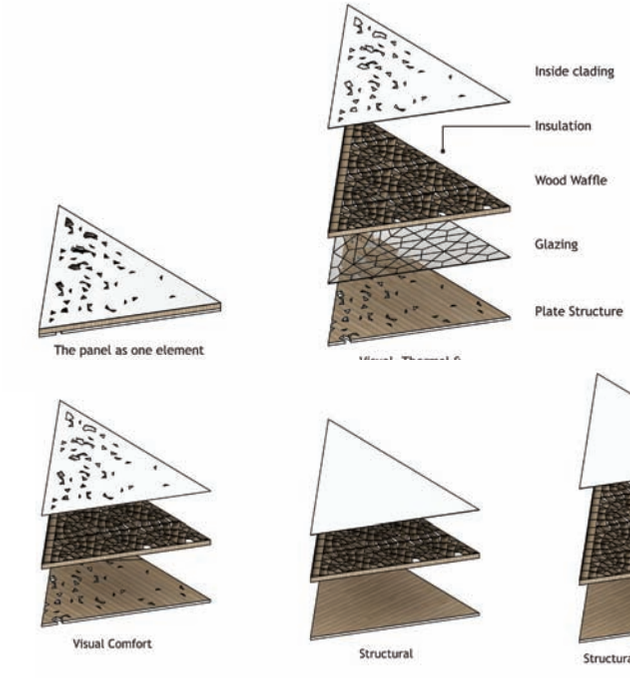
16 Fabricated model of panel — interior structure



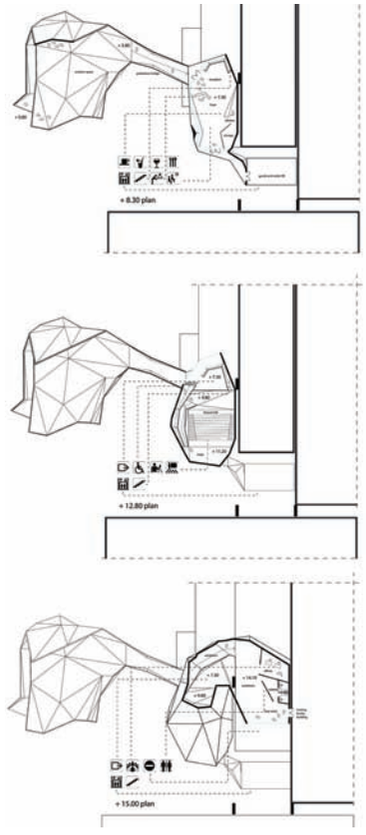
17 Fabricated model of panel — skin and apertures



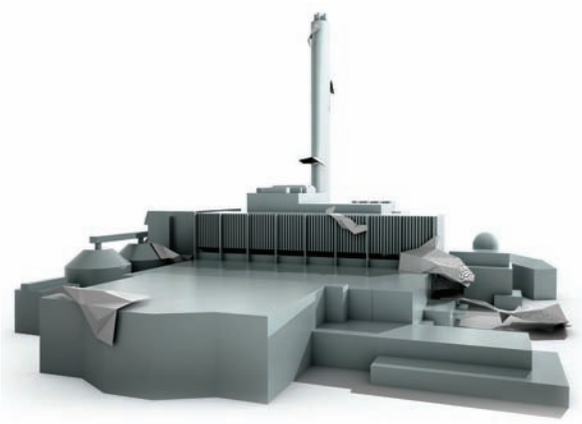
14 Internal waffle structure that allows apertures



15 Material composition of panel

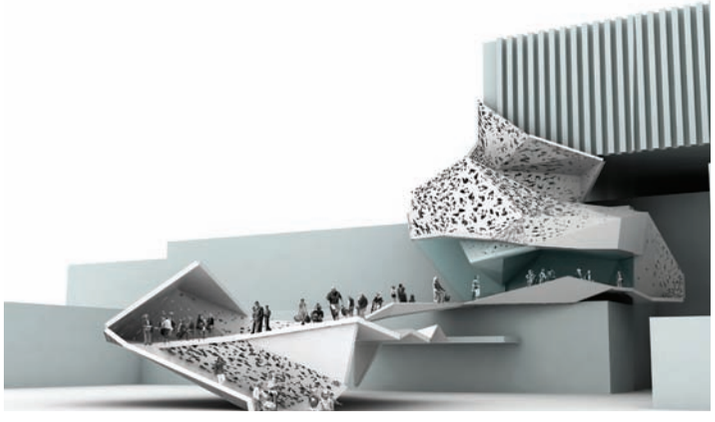


18 Planar sections through the main facility



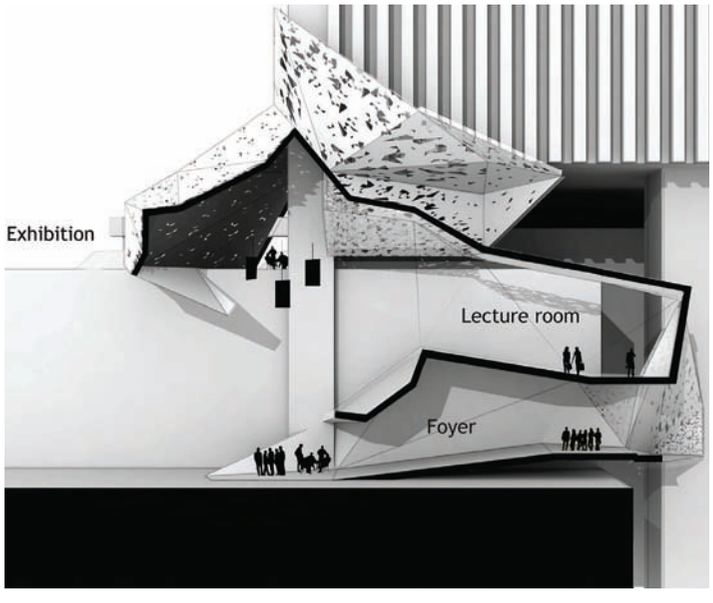
19 Massing study with additional cladding

20 Section through foyer,
lecture room and exhibition space



21 Massing study and
entry conditions

22 View from viewing
platform



23 Section through
lecture room

Amongst the Machines

Kathryn Bell, student KTH Studio 11, Final Project 2011

The development of a bio fuel- combined heat and power plant with an associated public program in the third and final semesters of the studio, the 'Amongst the Machines' proposal aimed at making the industrial qualities an aesthetic identity. Specific areas were selected for parametric development, while the industrial part of the program was facilitated in more rationally defined volumes. The given site in the Royal Seaport area of Stockholm provided the opportunity to include a sports center that would be easily accessible for residents in the area, while the industrial character of the site was seen as a basis for the design agenda.

Design narrative

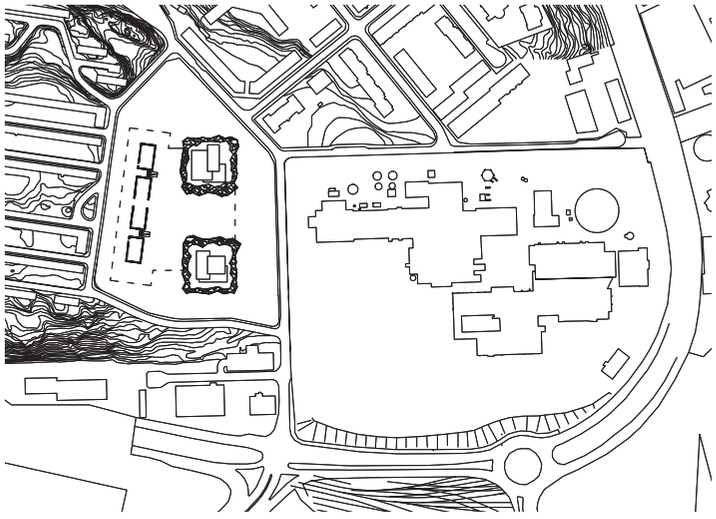
The particular circumstances of the given site afforded a situation in which an existing fossil fuel CHP plant (combined heat and power), to be transformed into a bio fuel, would be extended. This made possible the use of existing systems for fuel storage and handling, making the industrial part of the new program reduced. The urban situation in the Royal Sea Port set high design criteria, and also suggested that the required public program to be added would be easily accessed from nearby residential areas [01]. The main public program selected by the student was an extreme sports center, specialized into a climbing center and a skateboarding park. An early design statement indicated an ambition to employ the industrial character of the plant to develop aesthetic principles and spatial effect.

The project was developed in three phases, following the curriculum of the teaching studio. The first phase included the programmatic development, main massing and the identification of key areas for potential parametric development [02]. In phase two, a two-week intense study on these key areas, the focus was put on developing parametric strategies for the space frame and its associated articulated spaces. This work continued in the third phase, which also entailed a more refined iteration of the overall design, as well as the parametric development of the articulated façade of the boiler house and the articulation of the terrain [03 + 04].

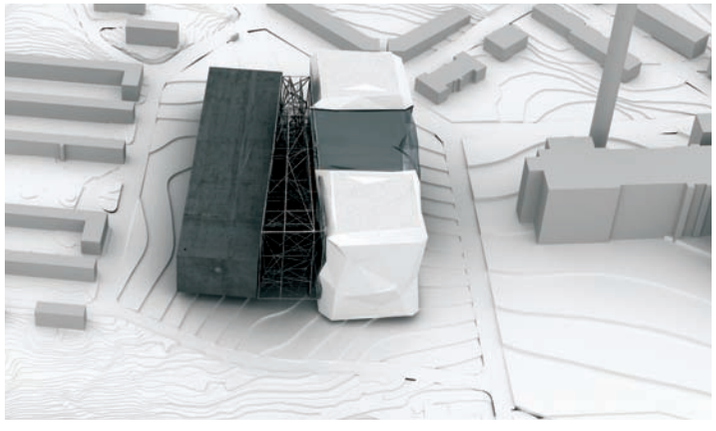
After initial programmatic studies, the student decided to divide the industrial program into two main parts, both to be housed within formally distinct envelopes. The Boiler House (facilitating the boilers of the plant) was identified as more prone to future expansion, which suggested a more flexible construction in steel [05]. All other industrial program parts would be fit into the other main volume, designated as the Bunker, with a main structure of concrete [06]. The additional public programs would be located between these two main volumes, as well as on the surrounding ground and on the roof. The two main volumes would also take on different architectural qualities; the Boiler House would be translucent and clad in triangulated metal mesh, allowing the machinery inside to be vaguely discerned [09 – 11], and the Bunker would be clad in concrete panels, with selected areas opened up and clad in glass panels [10 + 11]. Both volumes were defined as orthogonal boxes, set in the grid of the residential area to the west (Bunker) or the existing plant to the east (Boiler House). The tapering space between the two main masses would be featuring the climbing centre, and designed as an articulated network of spaces and structure suspended above the ground with fixtures to the two main volumes [08 – 11].

The theme of triangulated facets was used for the overall envelope of the boiler house, the openings in the Bunker [11 + 14], the space frame and associated structures [08 + 09] and the articulation of the ground [03 + 08]. At a basic level this re-use of the formal theme was aimed at creating a coherent formal concept that would allow differentiation in application in different areas. The terrain defines the area relating to the plant and allow for different types of public use, in effect an artificial landscape that follows the existing land, but in certain areas provides a more dramatic articulation. The Boiler House envelope retains a similar articulation of surfaces to create a distorted box, but incorporates the metal mesh for translucency and connection to the interior. The Bunker employs the theme for an articulation of the otherwise smooth surfaces of the envelope, providing wide apertures and a view of the internal structure. The two areas where the theme goes beyond formal and visual identity include the space frame and the associated climbing facility, and the entrance area. The entrance is located at the base of the bunker, where the ground is extended into the building and is deformed to allow vertical passage to the climbing facility [07 + 08 + 16]. The space frame provides support and formal principle for the enclosed spaces of the climbing facility, and also provides the support for the articulated climbing walls [09 + 14 + 15].

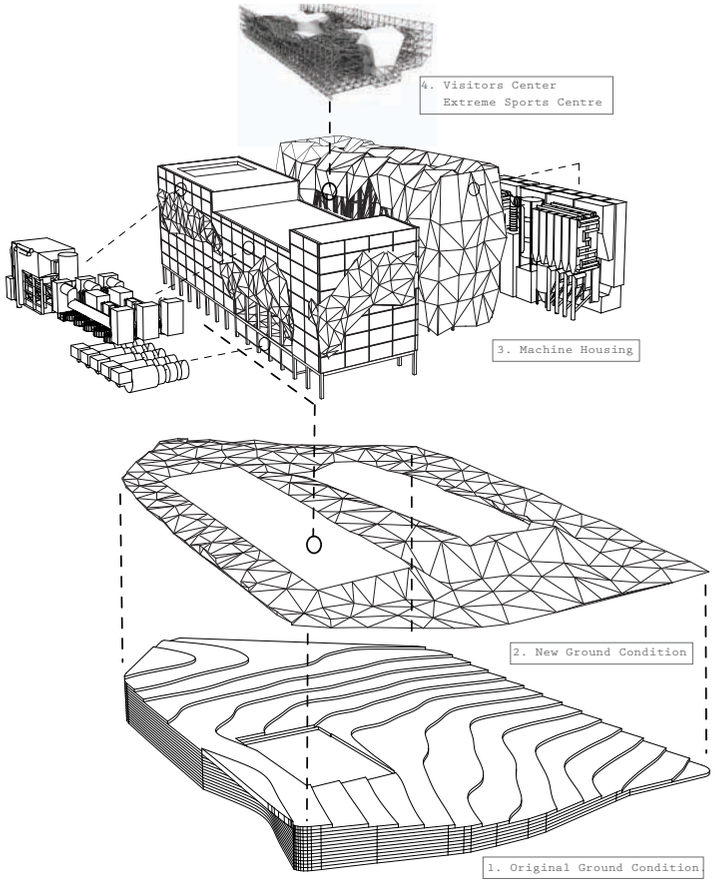
The use of parametric definitions entailed the development of a principle for the space frame, and associated cladding surfaces that were designated as the envelope for the climbing center as well as fragmented climbing surfaces, all suspended within the structure. This was developed in part, employing two frame work surfaces to provide depth and control of two layers within the space frame [12]. This allowed design control for space frame as well as cladding surfaces for the climbing center and the climbing walls [15]. The terrain articulation was developed through sampling points of the actual terrain, employing Delaunay triangulation to create the artificial landscape [13]. Control of the height of specific points allowed precise definition of key areas, such as the interface with the building volumes and the ramps in the entrance areas [16].



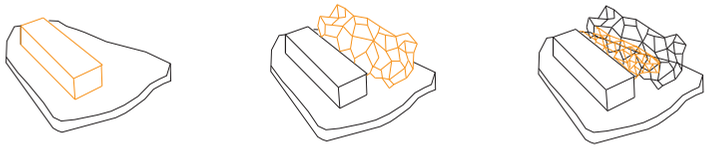
01 Site in the Royal Seaport area, near the existing power plant



02 First phase massing principle



03 Project components



04 Third phase massing principle

Digital design Techniques

The project primarily employed direct modeling, with selected project aspects featuring parametric modeling. While formal principles could be re-deployed in these different aspects, specific parametric models were developed for each situation.
[Contexts II: p.22, p.27]

Architectural Performance

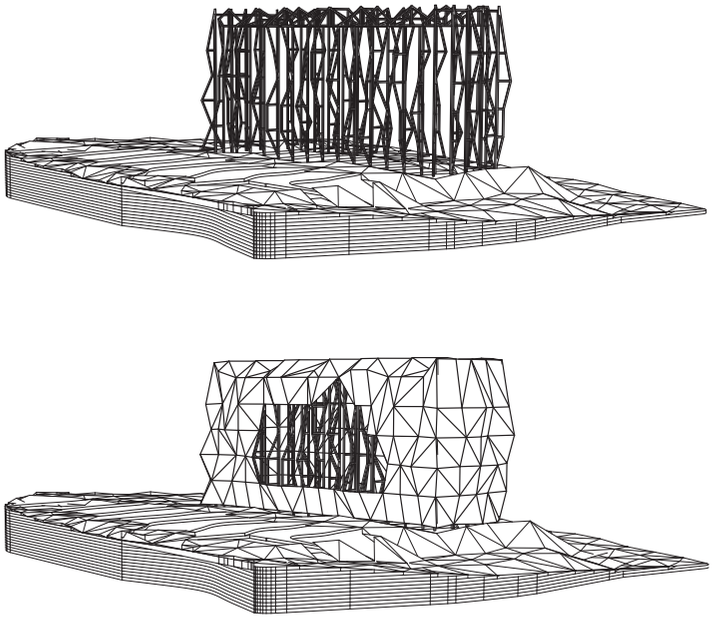
The formal principle of triangulation doubled as structural enabler in the space frame design, and became a reoccurring theme throughout the project. In most cases it frames the industrial expressions that bring identity to the project, and it also extends that expression into the landscape. [Contexts II: p.38, p.39]

Speculative Design Aspects

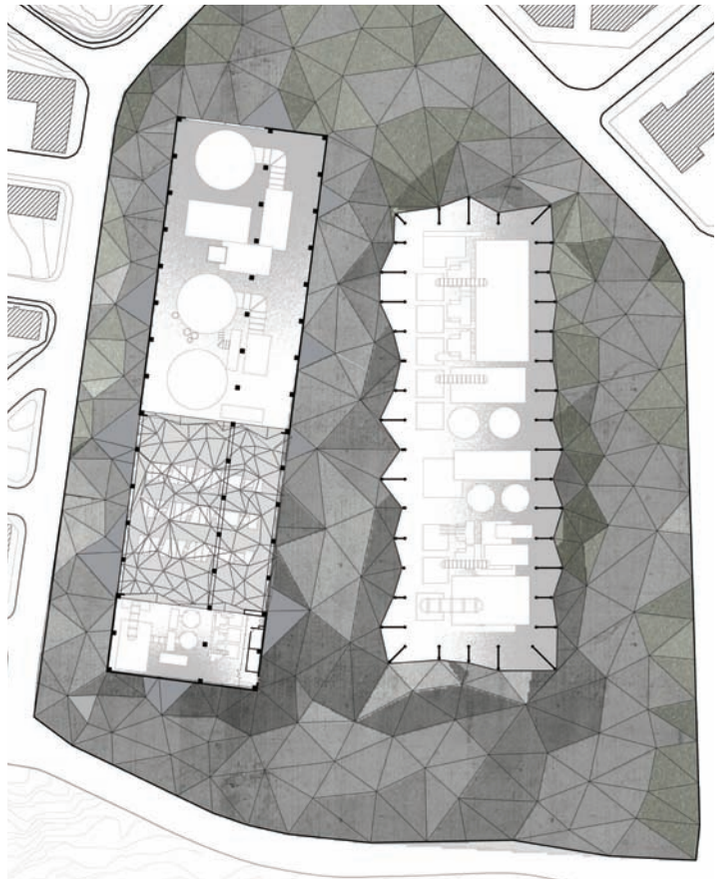
An important part of the project was the suggested mix of programs, in which cultural activities are mixed with industrial services. This entails a speculative on future use, based on an intuitive understanding of the sublime lures of industrial environments.
[Contexts II: p.60, p.61]

Digital Design Strategies

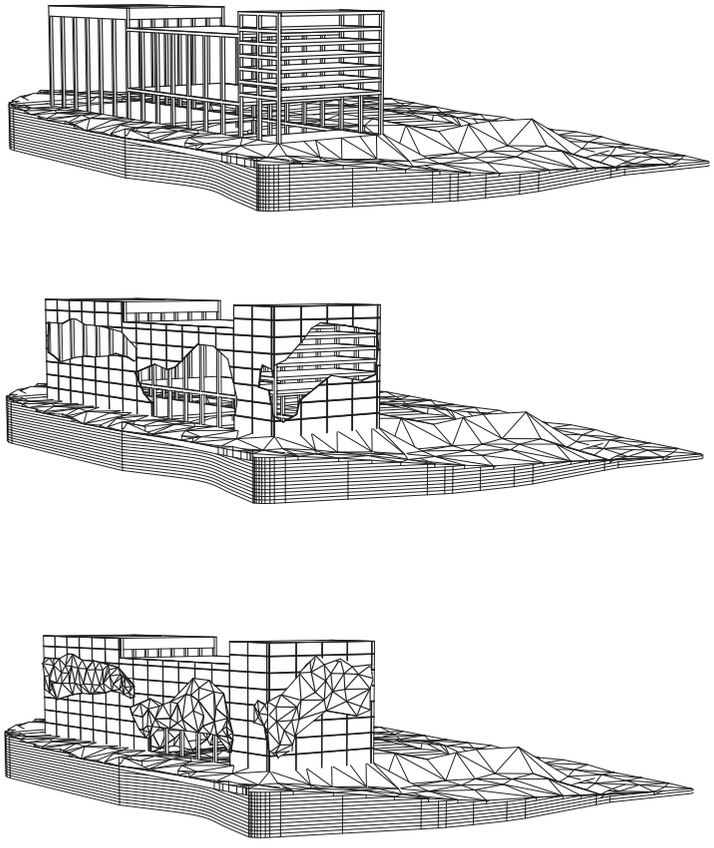
The project development originating in basic massing enabled the fragmentation of digital design deployments, allowing several independent design strategies in regards to project aspects. While they share a formal resemblance, they were developed as separate systems. [Contexts II: p.84, p.175]



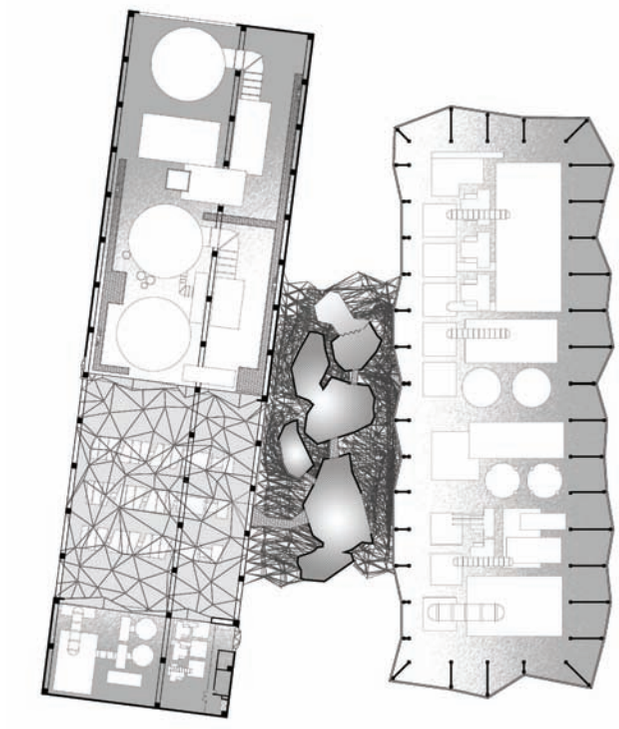
05 Boiler house composition



07 Ground level (+5) with bunker and boiler house

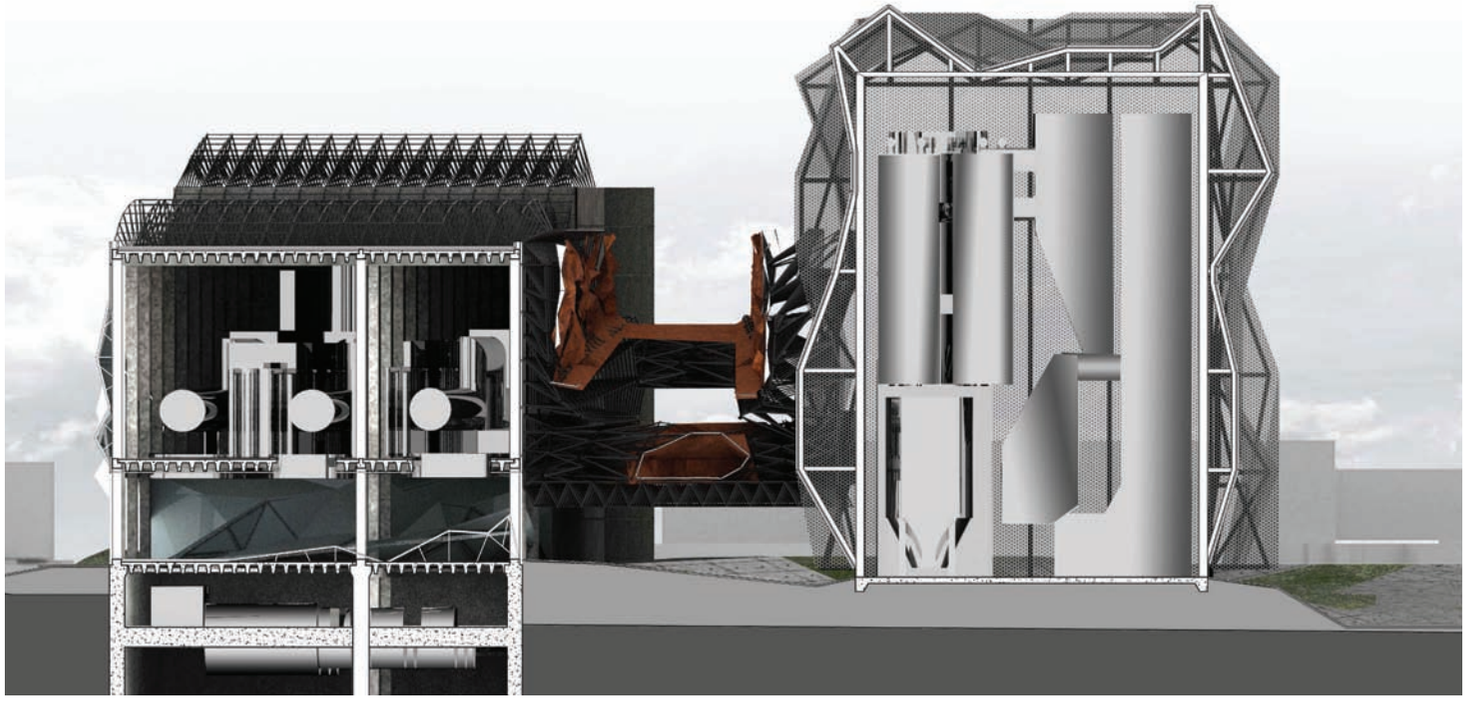


06 Bunker composition

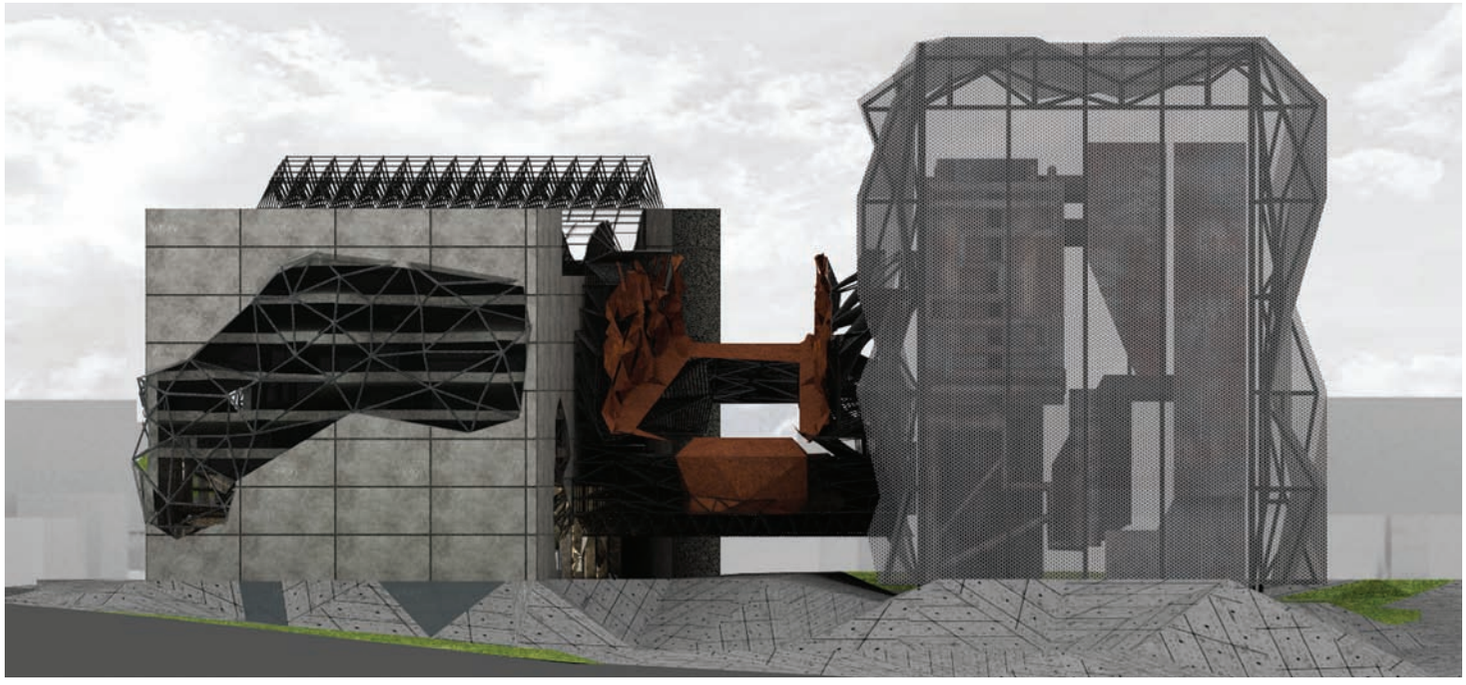


08 Upper level (+8) with entrance and climbing center

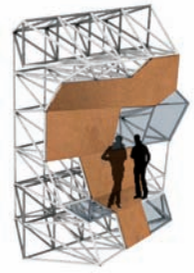
09 Section through climbing center, facing east

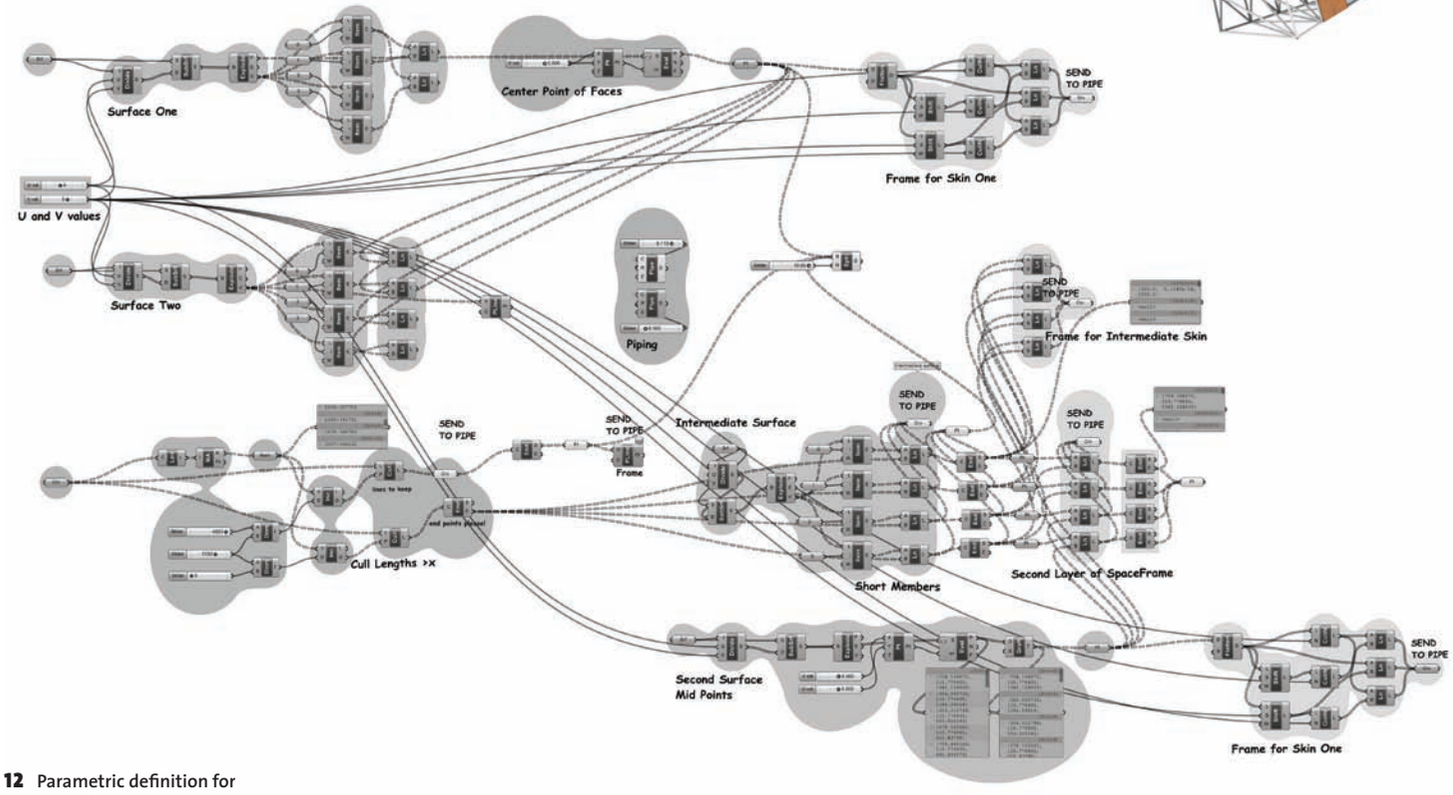


10 Cross section through bunker, climbing center and boiler house

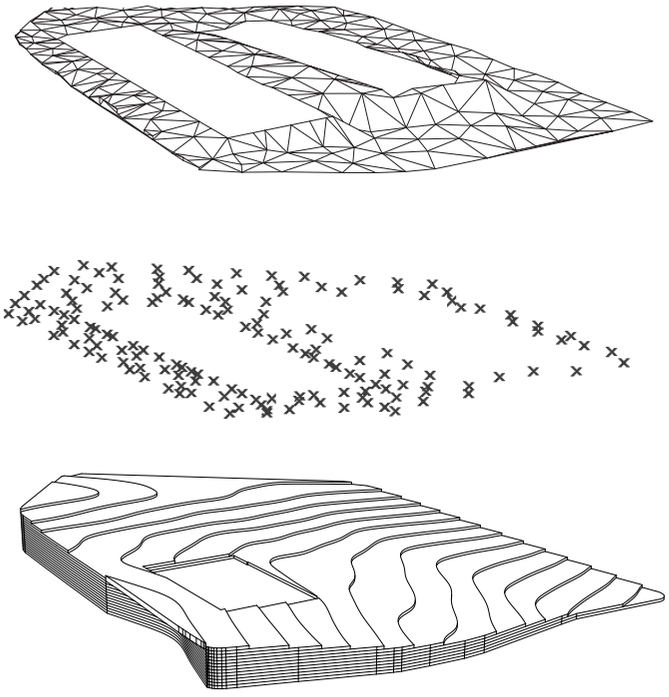


11 Envelope differentiation of Bunker and Boiler House

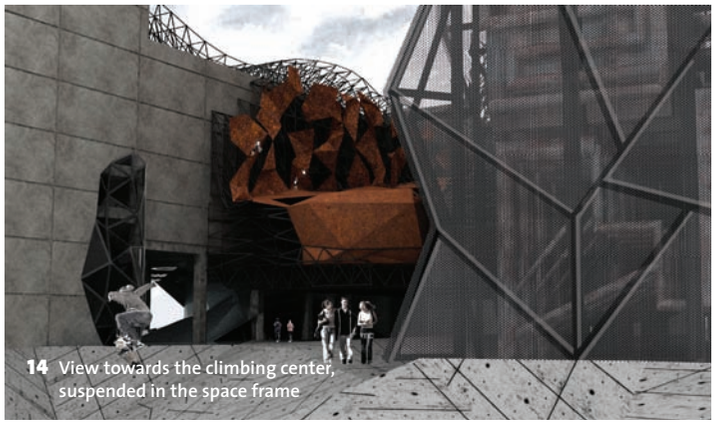




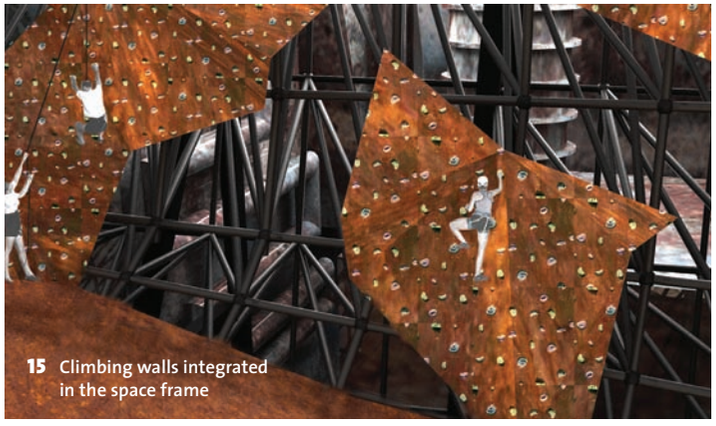
12 Parametric definition for space frame development



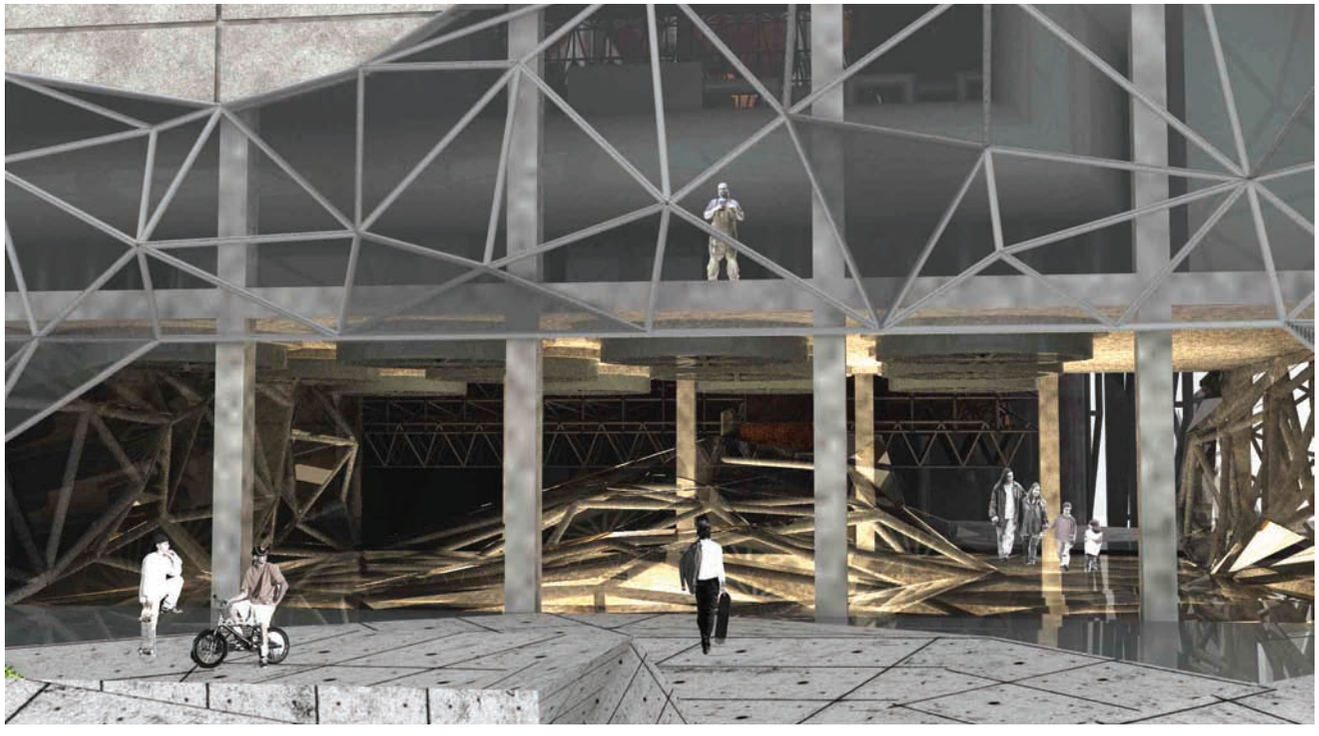
13 Existing terrain sampled through points



14 View towards the climbing center, suspended in the space frame



15 Climbing walls integrated in the space frame



16 View towards entrance, with the triangulated terrain opening up to basement and creating ramp

Subversive Resilience

Anna Teglund, student KTH Studio 11, Thesis 2011

A thesis project developed through an architectural speculation based on current technologies for algae production, the 'Subversive Resilience' project employs a systemic approach with aesthetic drivers. The premises explored are based on current technology still at experimental stage but deemed viable within a decade, and the proposal for an algae production plant with public functions suggests that these technologies are not only for industrial purpose, but can add spatial and architectural qualities. Based on existing conditions and planned extension of the Royal Seaport area of Stockholm, the site is an urban industrial area with plans for renewal.

Design narrative

The project was initiated through an in-depth study of photobioreactors for algal cultivation in regards to applications of micro algae, the technologies employed and the requirements for production at different scales. A main thesis was that micro algae farming can be conducted in an urban situation, and that the production itself could be articulated in an architectural way, thereby providing architectural elements that could on one hand enrich the spaces created, and on the other be part of making the processes involved visible and legible to the public. Key findings in the pre-study included the necessity of an abundance of CO_2 for industrial production (suggesting that a combined photo bioreactor and a CHP plant (combined heat and power). The project responds to this in the placement of the photo bioreactor adjacent to Värtaverket, a fossil fuel plant in the outskirts of central Stockholm destined to be trans-formed into a biofuel plant [01]. Initially the project included the design of a Energy from Waste CHP plant, but the considerations of the site, and its context, the Stockholm Royal Seaport and consultations with Fortum (owners of existing plant) led to the decision to base the design on the adjacency of the new biofuel plant and restrict the work to the photo bioreactor and affiliated public functions. The technical aspects of algae farming were informed through consultation by Fredrika Gullfot, PhD and entrepreneur, and the recent founder of SimrisAlg, planned to be the second industrial scale micro algae production plant in Sweden.

Important prerequisites included the sun conditions on the site, which were evaluated in order to find the optimal footprint and orientation of the project [02 + 03]. Formal massing studies were based on the structural principle of the catenary chain, which were approximated within the parametric modeling package [04]. Additional structural simulations investigated the performance of a diagrid that combines the catenary cross section with formally derived building masses [05]. The system for algae growth was allocated in plastic tubes inserted in the structural framework, studied through a series of physical and digital models [06 + 07]. This was further detailed in models and drawings. The formal intersection of the two associated building models turned out to be quite complex due to the structural system, but this provided formal opportunities for alternate intersection principles, in turn resulting in articulated passages between the two interior spaces [09].

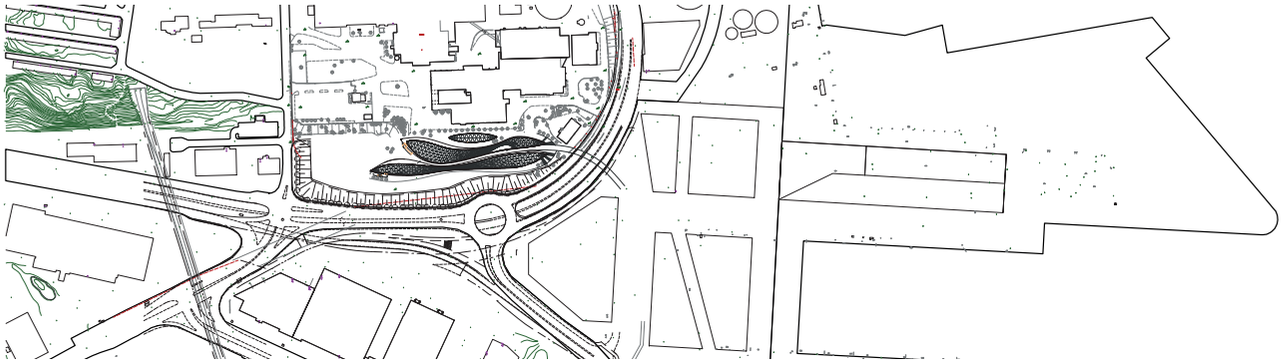
An overall system diagram was developed in order to relate non formal aspects of the building system with formal, structural and experiential qualities. This diagram was also crucial for the communication of the project as a system, and provided insights in the technical solutions for different types of building performances [10]. The relations to the surroundings were primarily investigated in the site plan, which also shows the public space passing between the two volumes [11]. The interior spatial organization was studied in model, but further refined in a series of floor plans [12]. The spatial qualities were also studied in the model, but was later further refined and communicated in a series of sections [13].

The building combines three main programs. As an industrial plant, it includes systems for algae production integrated in the design and construction of the building. As a research facility, it includes private areas for laboratories and access ways. Algae production is an emerging technology, and the proposed research would include studies on alternate algae growth processes as well as varieties of species. It would also study the conditions of algae farming, i.e. an urban farm. The third program is public, and includes interactive labs and views of the production, as well as a public restaurant. The programs are spatially distributed in a way that allows both interaction and seclusion [14].

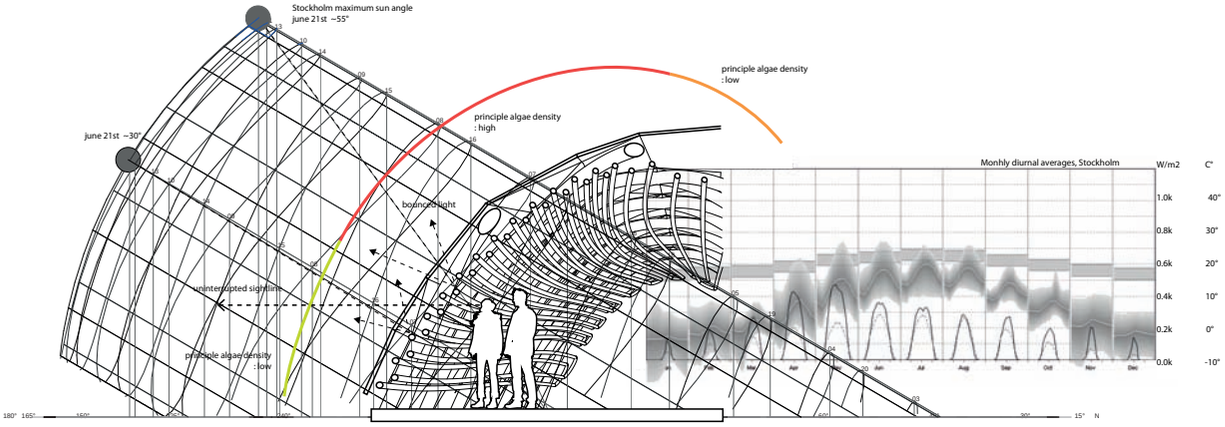
As a design exploration, the project studied experiential effect through renderings and collages [15 – 18]. Furthermore, a number of parametric system models were used, initially as a way to organize space [19]. This was abandoned due to the systemic inconsistencies of the required spatial configurations, and the parametric system was instead re-applied to configure the arrangement of algae tubes [20]. The combination of structure and tubes was the main spatial definer, but additional spatial differentiation was provided by the articulation of the ground levels [21 + 22].

Digital design Techniques

Parametric modeling was primarily used to design and evaluate overall form and its structure, with additional studies for the configuration of algae tubing. More refined development was done through direct modeling. [Contexts II: p.22, p.27]



01 Site in Värtahamnen, part of the Stockholm Royal Seaport area



02 Sun angles of site

Architectural Performance

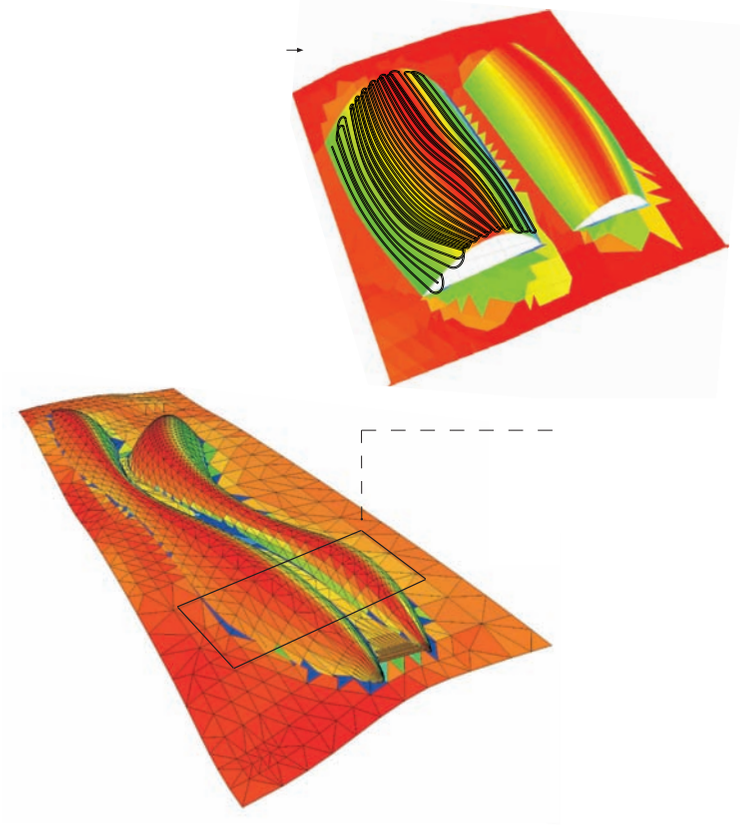
The project combined technical performance with architectural expression in several ways. The overall form and structural systems facilitated the massing and main interior spatial qualities.
The technical systems of the algae farm added an additional layer of articulation, filtering daylight into the interior spaces.
[Contexts II: p.38, p.39]

Speculative Design Aspects

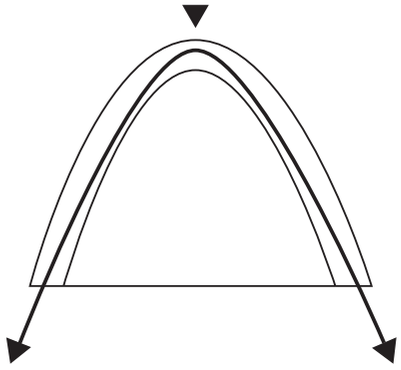
The project was based on an extrapolation of present technologies in regards to algae farming, adapted to an architectural agenda. This set the conditions for all further design.
[Contexts II: p.60, p.62]

Digital Design Strategies

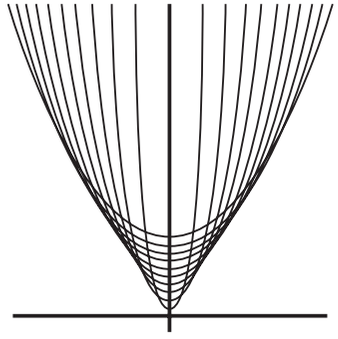
The project combines digital design development in several project aspects and several types of engagement. They are interrelated through the overall form at a conceptual level, but as parametric systems they could be independent. [Contexts II: p.84, p.175]

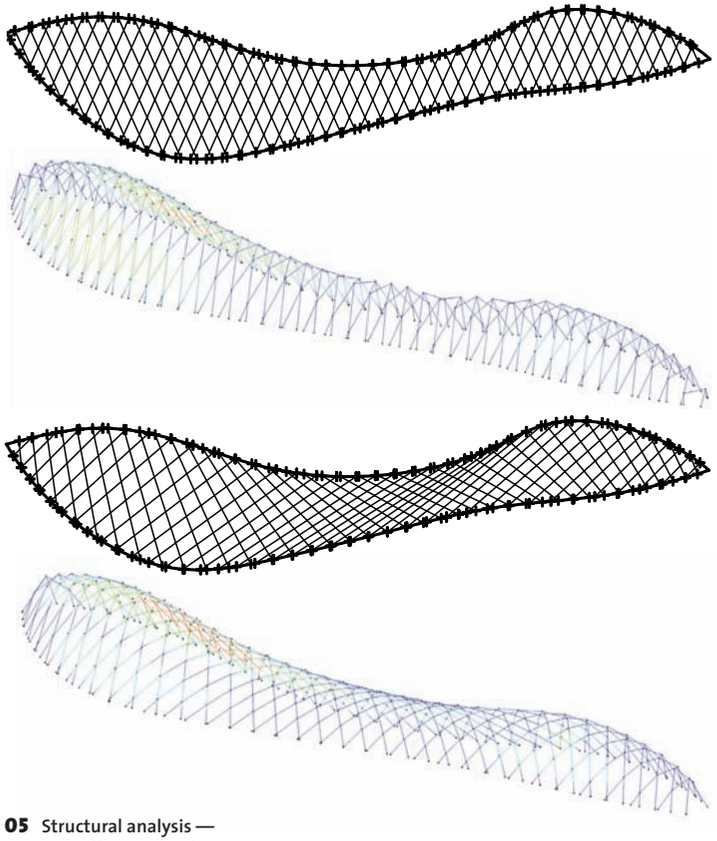


03 Analysis of solar irradiation levels of site and massing, to define optimal placement of algae growth tubes

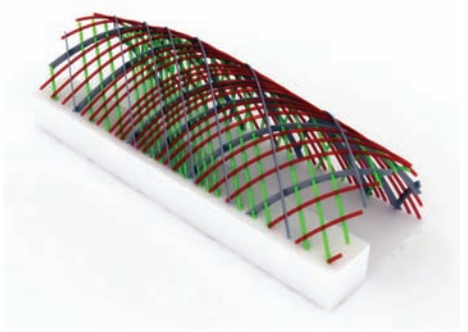


04 Structural catenary principle — section



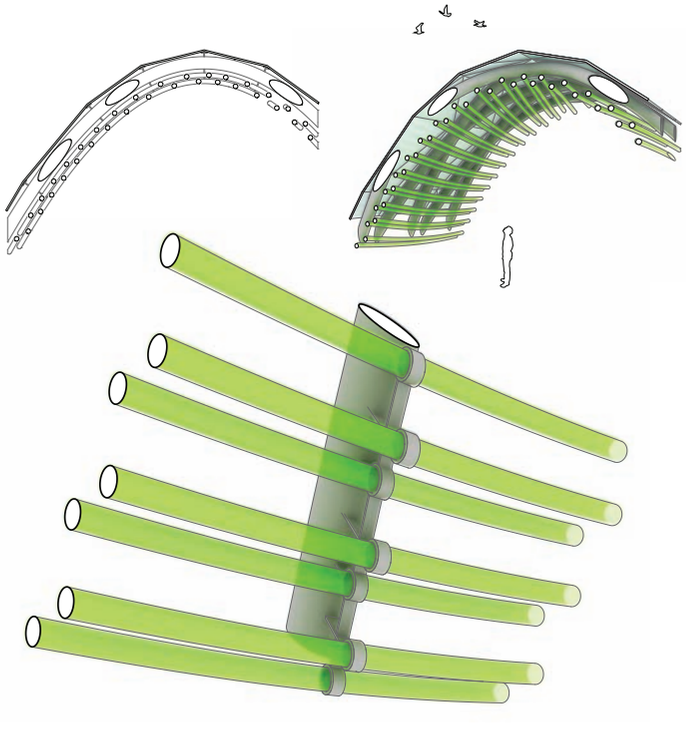


05 Structural analysis — deflection of diagrid

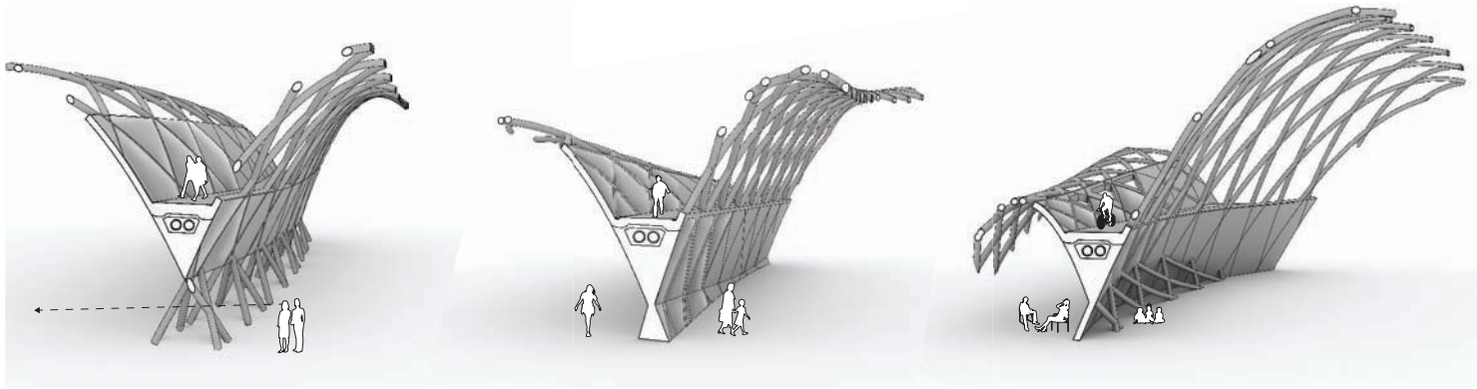


06 Placement of growth tubes, rendered model

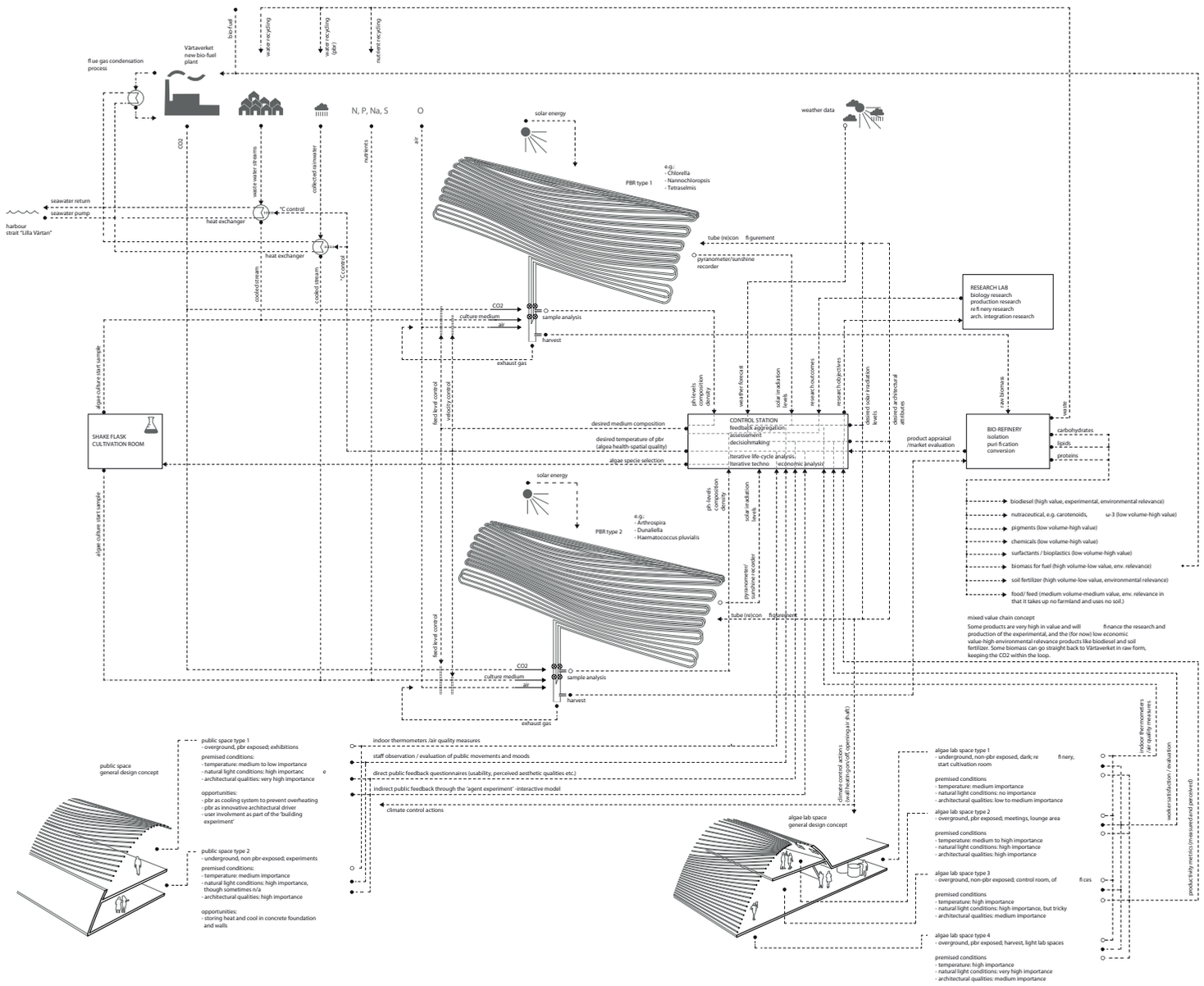
07 Placement of growth tubes, early physical study model



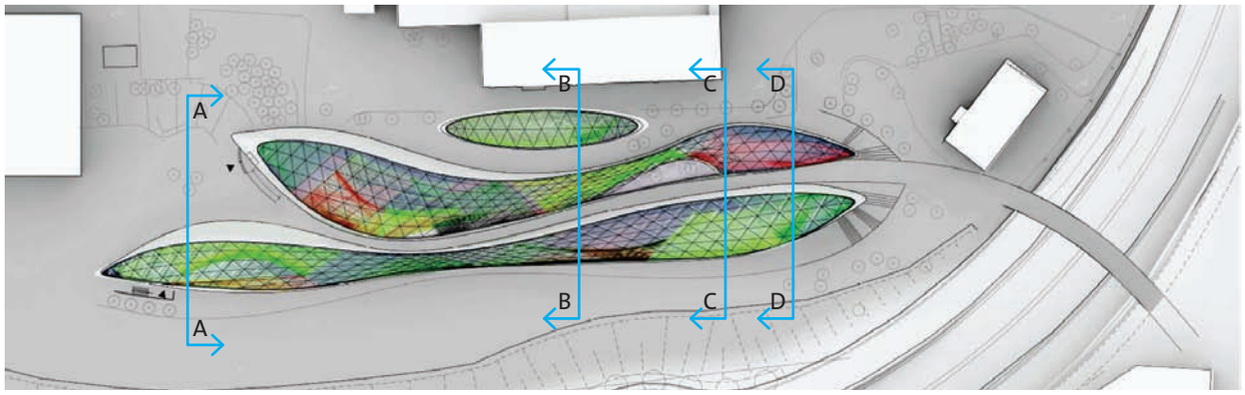
08 Placement of growth tubes — final proposal



09 Principles for the intersection of separate structural systems

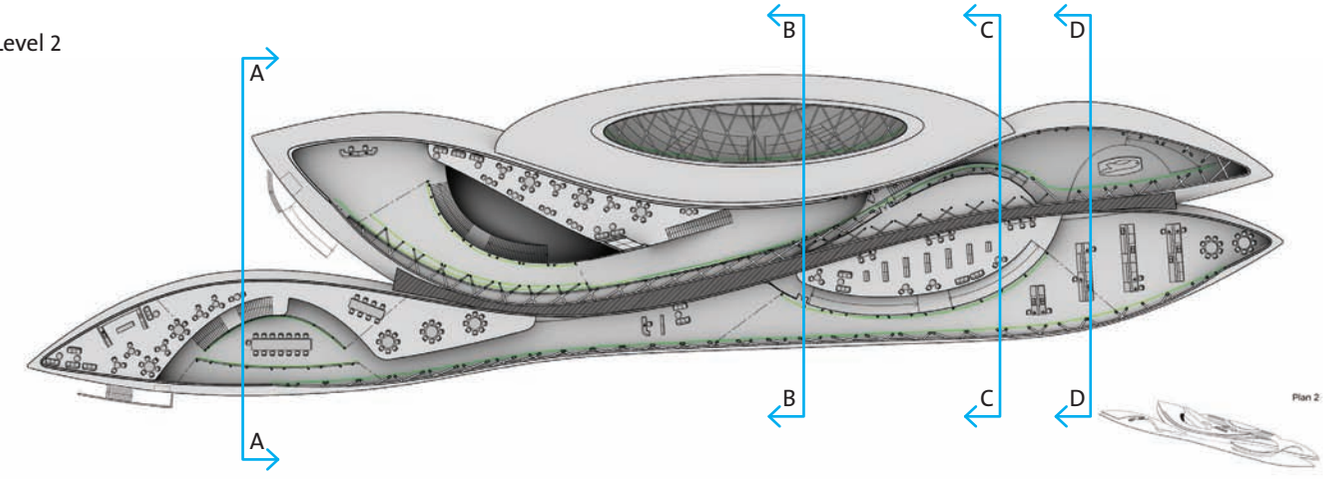


10 System diagram of production systems and spatial interfaces

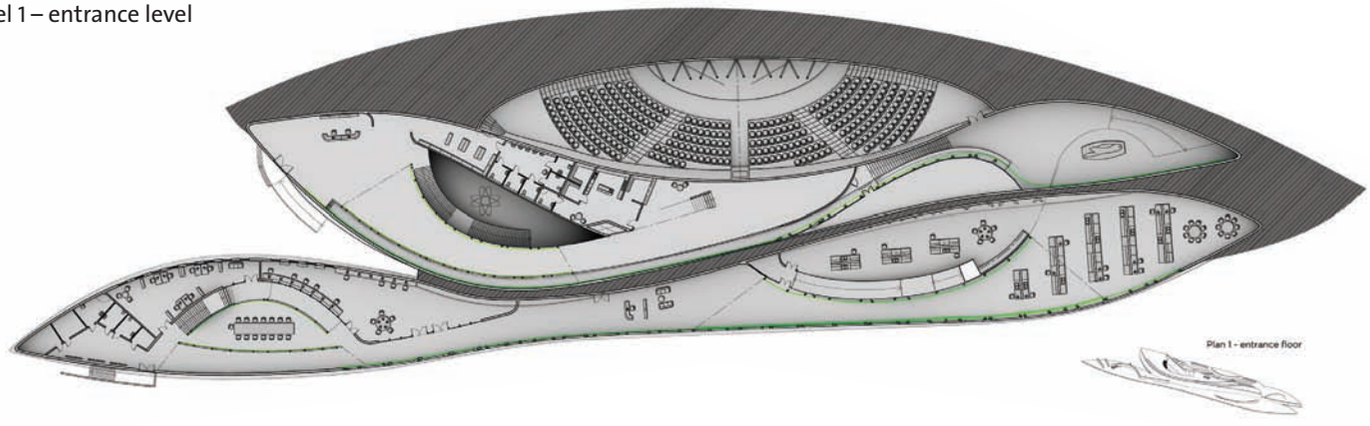


11 Roof plan with algae articulation

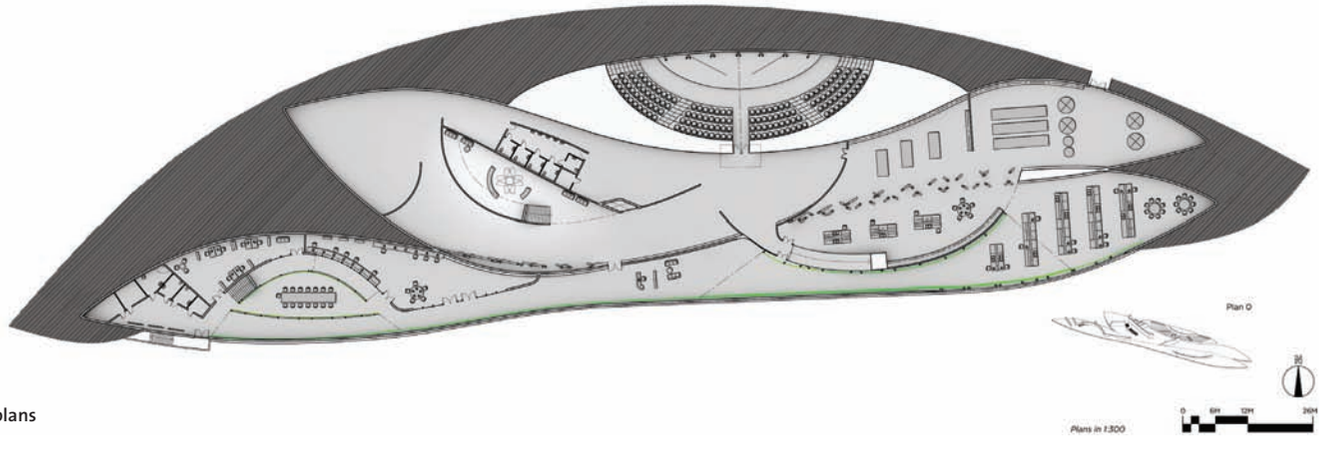
Level 2



Level 1 – entrance level

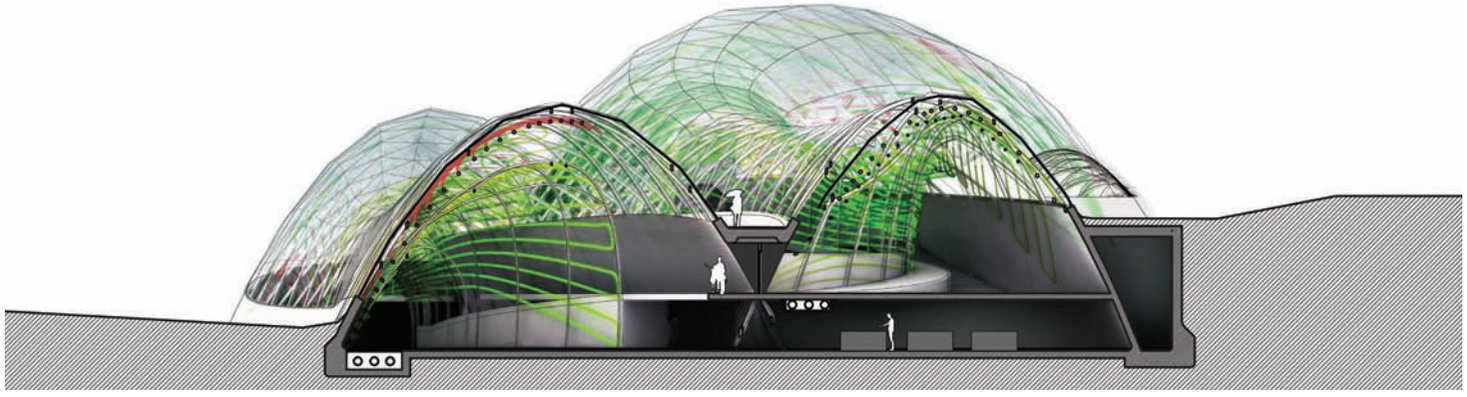


Level 0

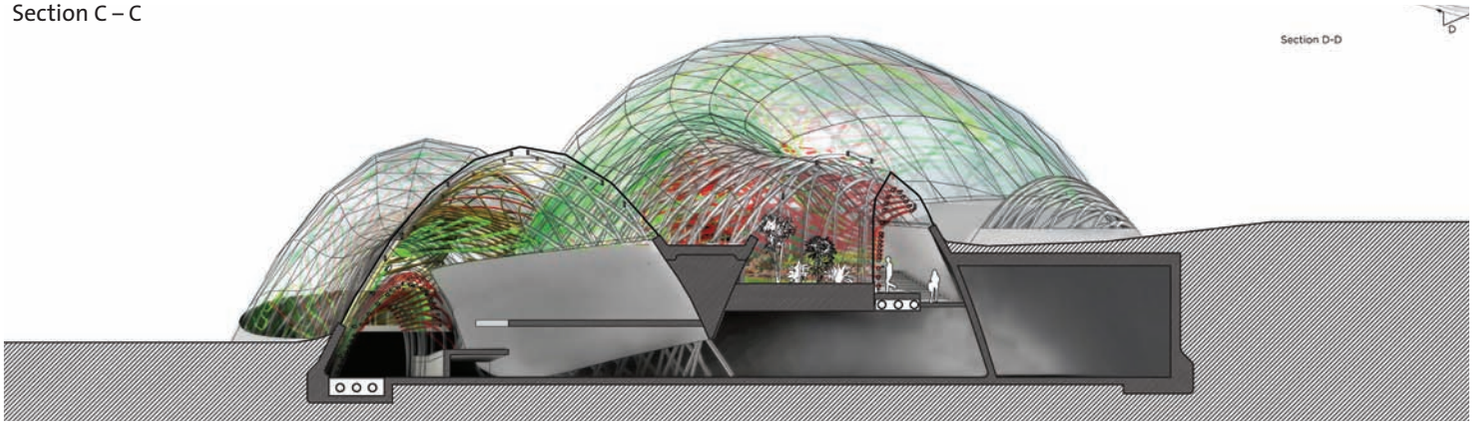


12 Floor plans

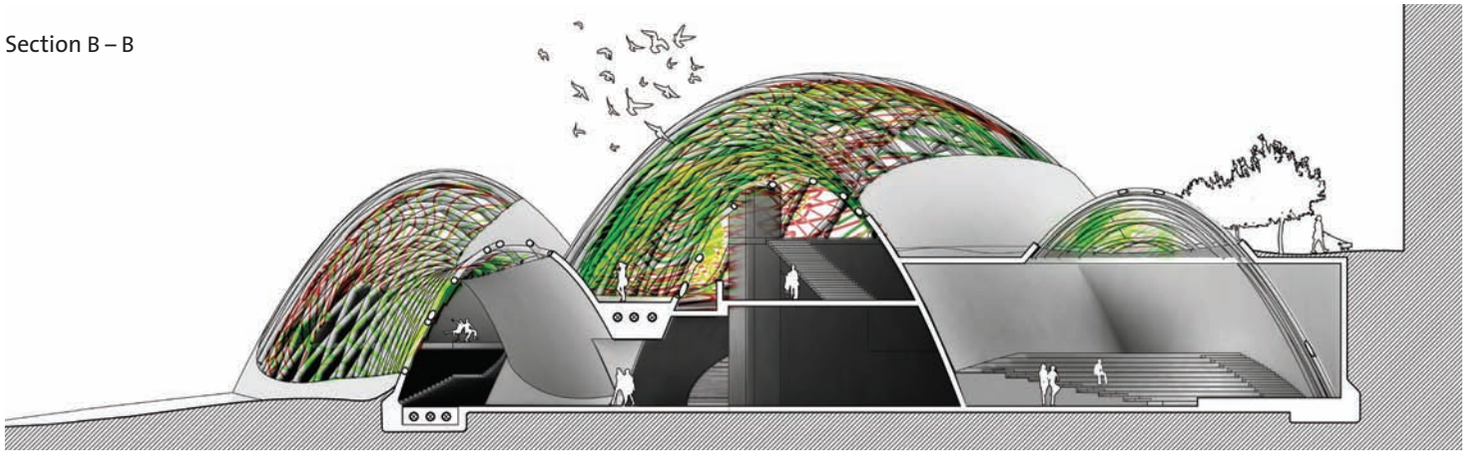
Section D – D



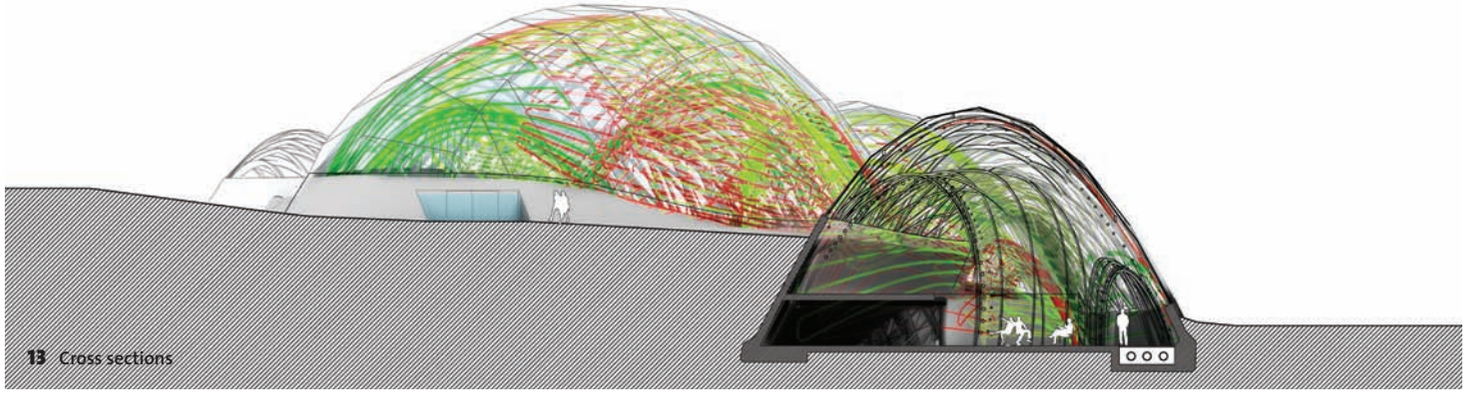
Section C – C



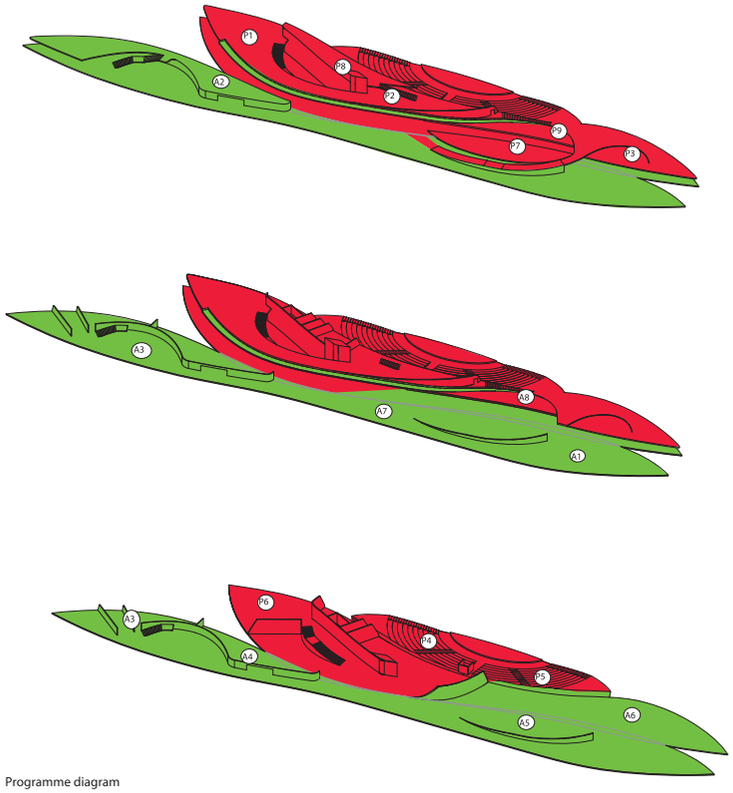
Section B – B



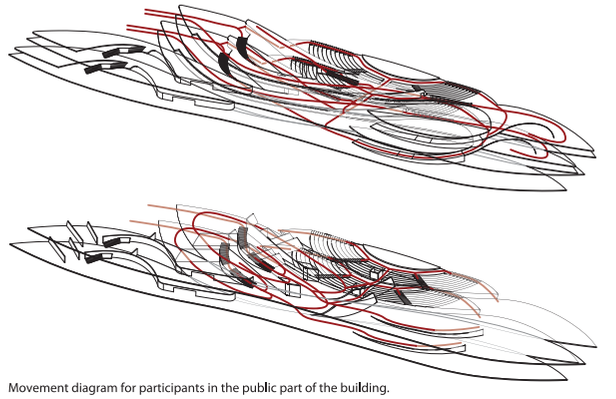
Section A – A



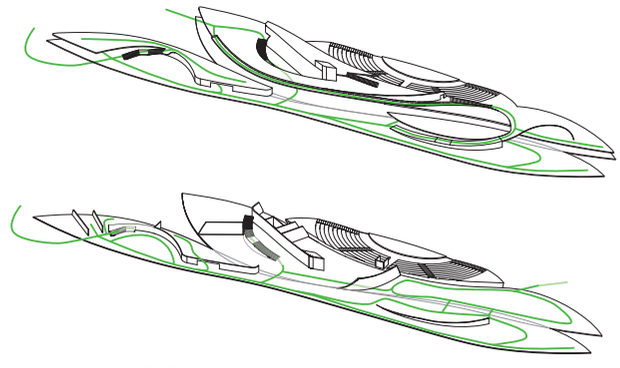
13 Cross sections



Programme diagram

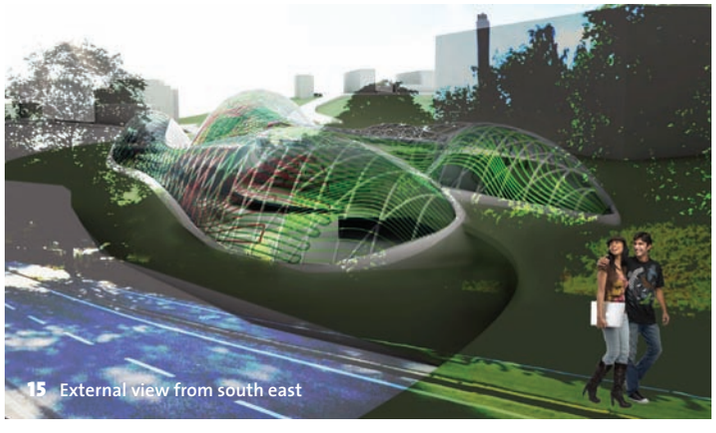


Movement diagram for participants in the public part of the building.

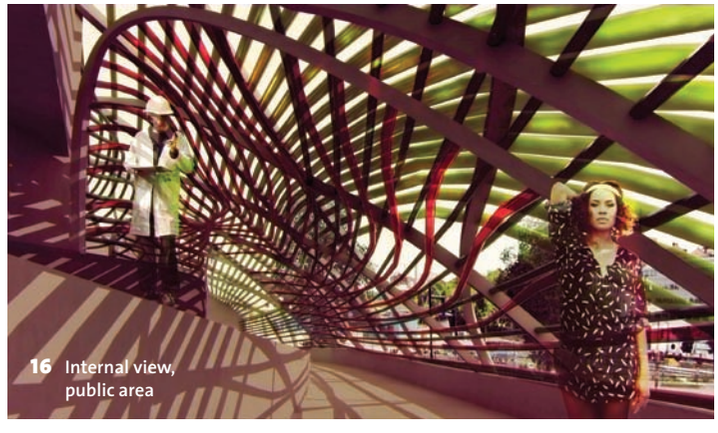


Movement diagram for algae lab workers and researchers.

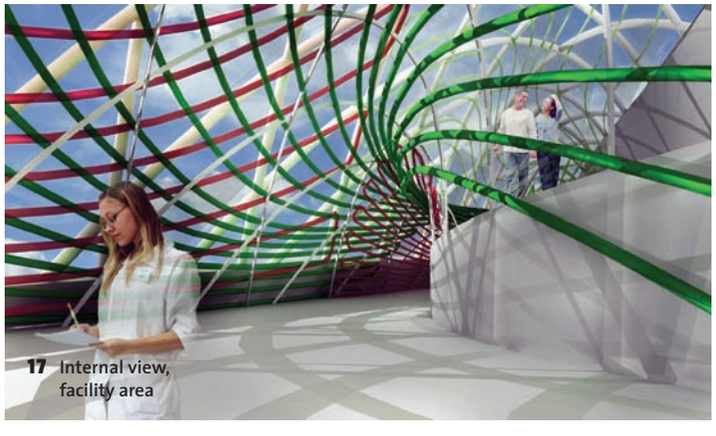
14 Program distribution and movement diagrams; public in red, facility staff in green



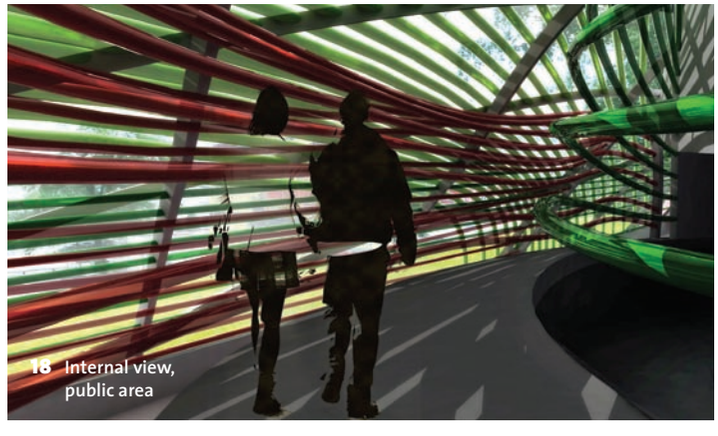
15 External view from south east



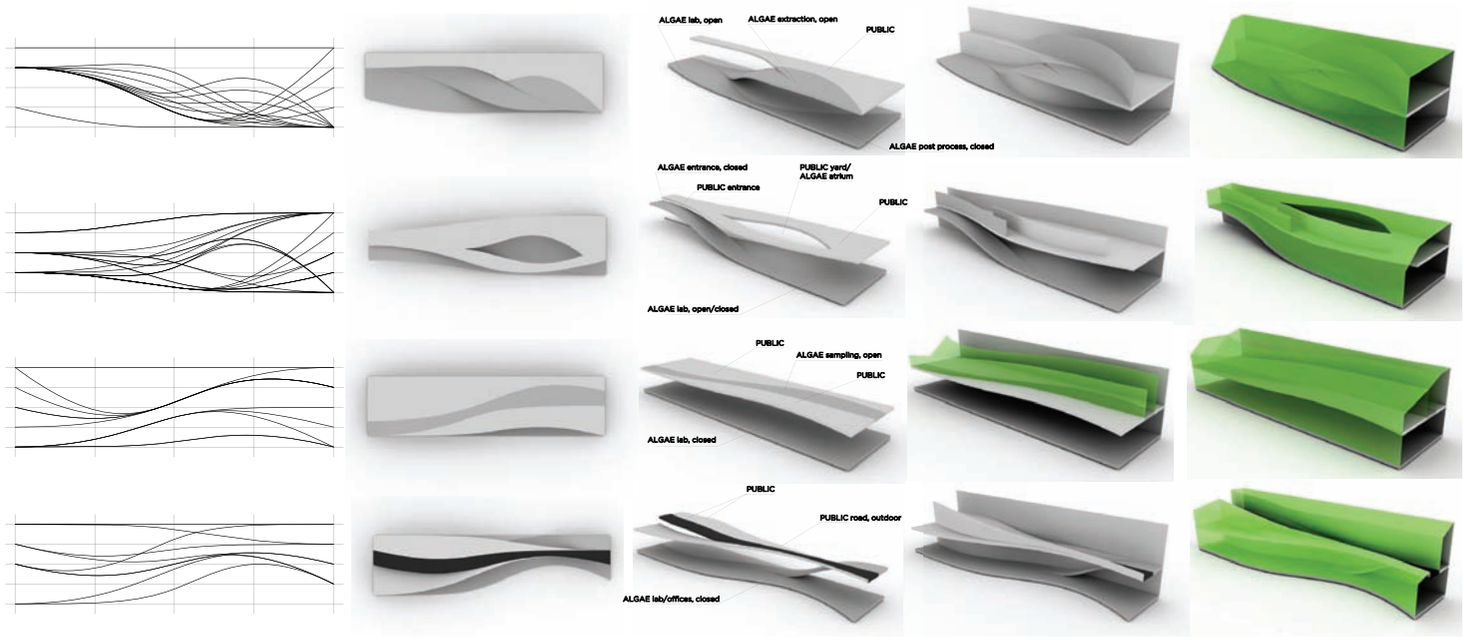
16 Internal view, public area



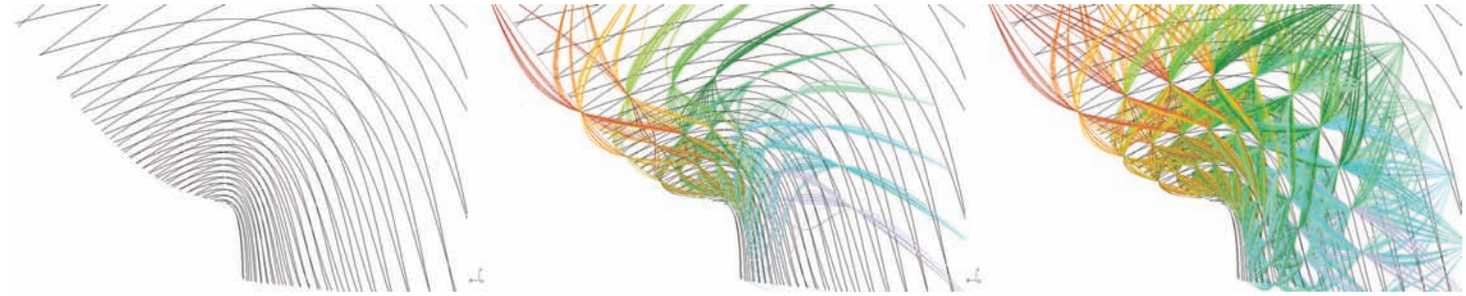
17 Internal view, facility area



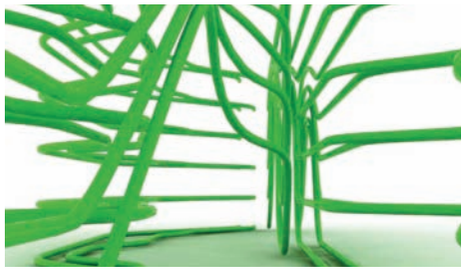
18 Internal view, public area

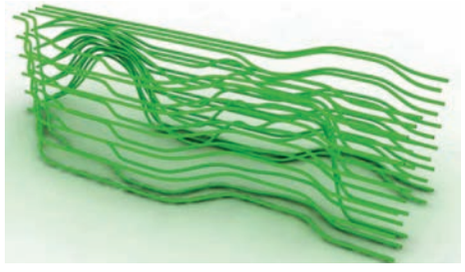


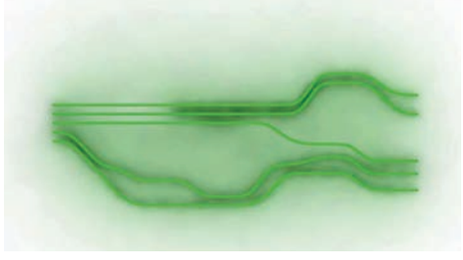
19 Initial parametric spatial and programmatic models



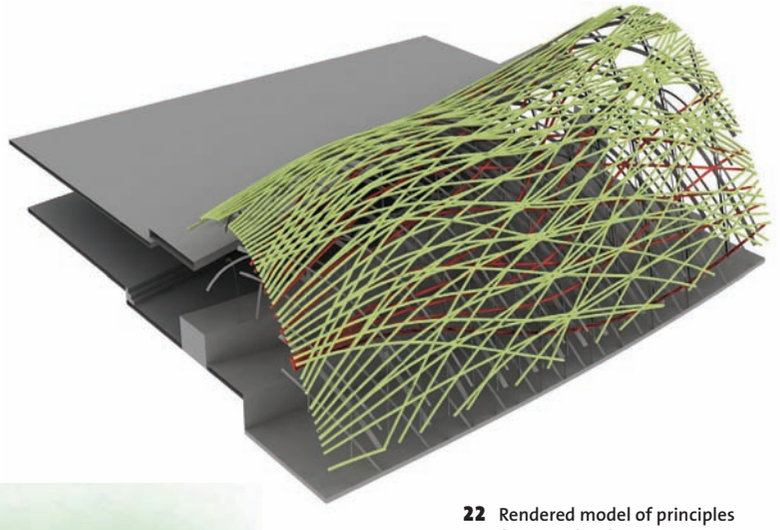
20 Parametric models of tube configuration







21 Tube configuration, early studyplatforms, elevation and section



22 Rendered model of principles for growth tubes set in structure

Koggen Ornament

Jonas Runberger, Dsearch, White arkitekter 2010

A formal principle linked to a parametric system for ornamental variations in concrete façades, 'Koggen Ornament' was developed at a late stage of the overall development of the Koggen residential project. The objective was to develop a differentiated pattern to be set in pre-cast concrete elements to be employed in selected parts of the building, and beyond the formal geometries developed, the parametric design system also allowed a non-specialist to interact with the model, to explore variations of the design theme.

Design narrative

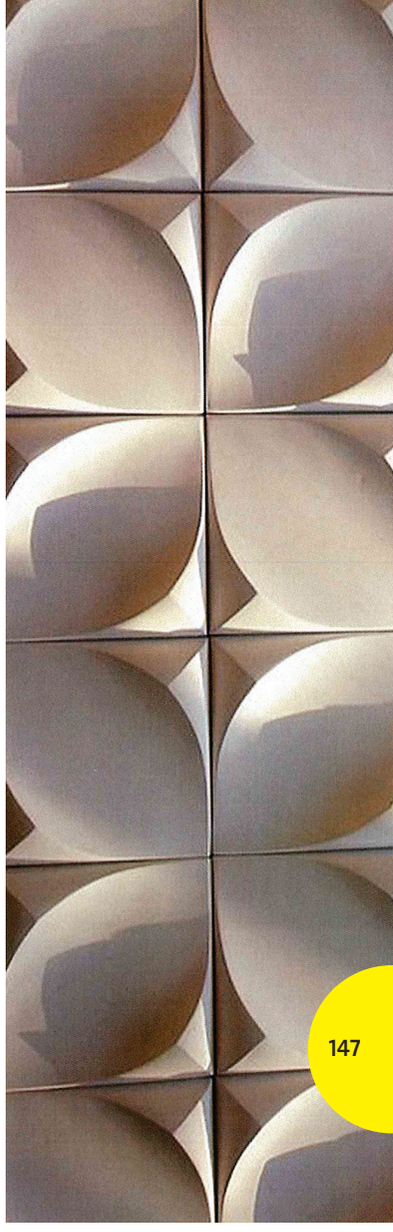
The development of an ornamental system for integration in the kv Koggen design build project at White was initiated very late in the project process, based on the possibility to produce custom m olds for a number of pre-cast concrete elements, and located around the entrances at ground level [01]. The task was to design a base pattern with depth as a system that could be explored in a number of variations, based on initial references [02]. The basic principle for the ornamental system was based on a rectangular grid, and a simple component of surfaces formed by a number of diagonal lines. The primary parametric variation is generated by shifting control points that defines the curvature of two particular curves, creating the effect of an opening and closing form. These lines also provided ridges in the relief to define how lights cast shadows, and are mirrored across the diagonal axis of each unit. In the symmetrical configuration, units were combined in sets of four, but each individual unit still had a specific input value for its primary variation [03]. With a façade of 40 meters, a slow variation could be developed, that at first glance would look repetitive, but which at closer look would provide a slightly different identity as you move along the façade [04]. Over a larger surface this transformation could be very gradual, and there were no fixed steps, based on the production principle of a customized milled cast; while the organization of the surfaces was divided up in individual and grouped units, the overall population of a prefabricated element could be seen as a non-uniform field [05].

The basic element could be applied in an asymmetrical mode, in which the parametric element would be repeated across the surface with a smooth transition [06 + 07] or a symmetrical mode, in which a checkered pattern principle would make every second unit rotated 90 degrees, which in effect made an additional pattern emerge across sets of four units [08]. This was particularly apparent in the way that several characteristics can be gradually transforming across the surface independent of each other, while being combined in the particular form of each unit, such as the shift of aperture and curvature [09]. In addition, the grid that divided up the element could be distorted through a manual operation of points and lines that attracted or repelled the base geometry; in effect moving individual points of the grid towards or away from the attractor geometry [10]. This would alter the size and formation of local and adjacent units, while the internal parametric "aperture" variation – the formal opening and closing – is controlled through a global mechanism.

The parametric model for a particular element had a number of associated control surfaces - diagrams that controlled local values sent as input to each individual unit. Each unit had a corresponding point on the control surfaces, and the z-value of that point is direct local input parameter to the unit. As the overall control surface was manipulated dynamically, the z-value of each point is registered, listed and transmitted to the parametric model [11]. The amount of curvature controlled how fast transitions between units are facilitated. The control surface became a template for a particular input, and could be stored and reused at another time. While the aperture deformation of the units was the primary effect achieved, additional control surfaces were guiding other principles, such as the cull of the lines in each unit. This allowed for a transition from a more angular design to a smoother and curved one [12].

The grid generation definition was based on the input of a surface; a digital representation of the prefabricated element to be produced, on which a matrix of points was set (with potential variation of density). This point grid was then used to set a grid of lines, which were intersecting to form individual panels that would carry the individual unit. This association of individual units could have been applied directly to the initial point grid, but the step to grid lines enabled the deformation definition to affect the grid before applying the units [13]. Each attractor (or repelling) point used its own definition, but the total transformation of the grid was an interpolated result of all deformation inputs. The unit generation definition was set up a number of curves based on the panels of the grid. A number of points were set to depend on numerical inputs that in turn set the aspects such as the aperture control and the cull of the curves. The numerical inputs were derived from the definitions of the control surfaces, where each type of control surface had its own definition, with customized transformations of the control surface z-values into the appropriate parameter [11 – 13]. Apart from the parametric control through the surfaces, which allowed manipulation of Rhino geometries to affect the geometrical output from Grasshopper, there were a number of parameters that were manipulated within Grasshopper. These included numerical sliders for the resolution of the grid and the amount of distortion generated by attractor points and curves and the range of the distortion.

01 Kv Koggen, White arkitekter AB.
Facade aspect for ornamental application in cyan



02 Formal reference,
Dune Wall tile,
Urbanproduct

Digital design Techniques

The complete project aspect of relevance here was developed through parametric modeling, with specific emphasis on enabling non-specialists to control design variations through direct modeling manipulations. [Contexts II: p.22, p.27]

Architectural Performance

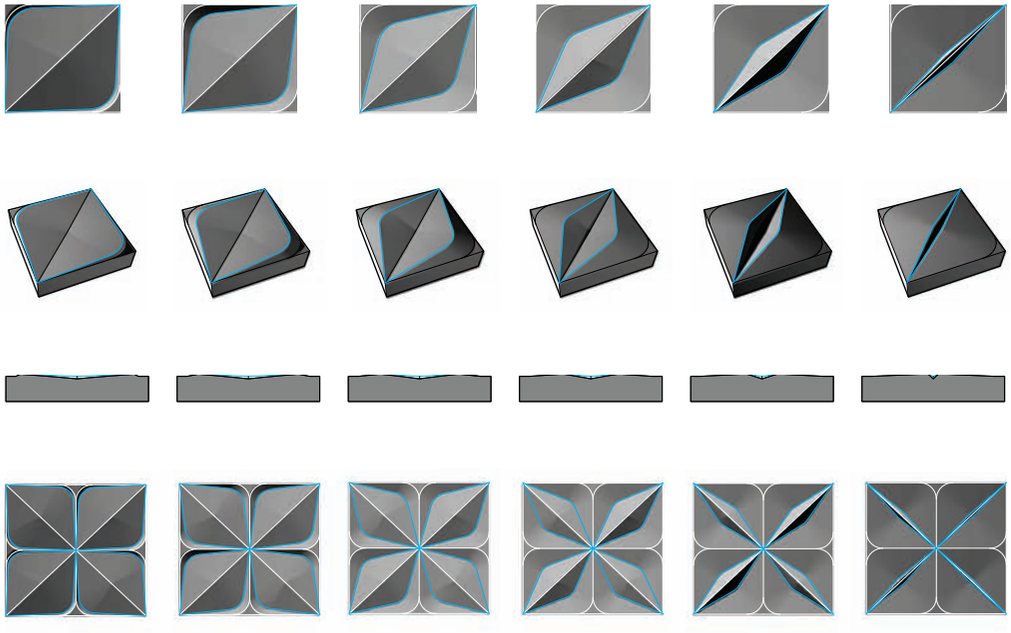
With an architectural performance limited to the articulation of surfaces for visual and tactile experience, the main technical performance of the project lied in the potential for non-specialists to engage in the design, with a direct influence on the variations of form. [Contexts II: p.38, p.40]

Speculative Design Aspects

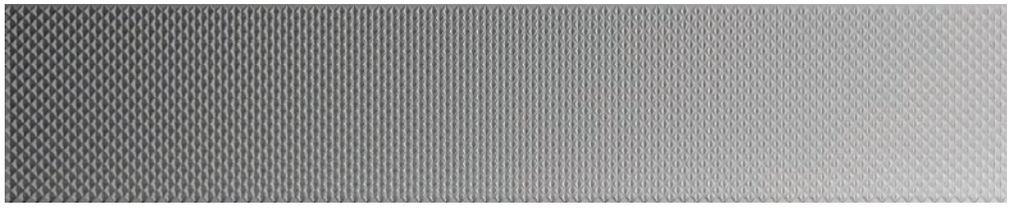
In analogy, the project speculated on future collaborative models supported by parametric design, based on the direct manipulation of control surfaces. [Contexts II: p.60, p.61]

Digital Design Strategies

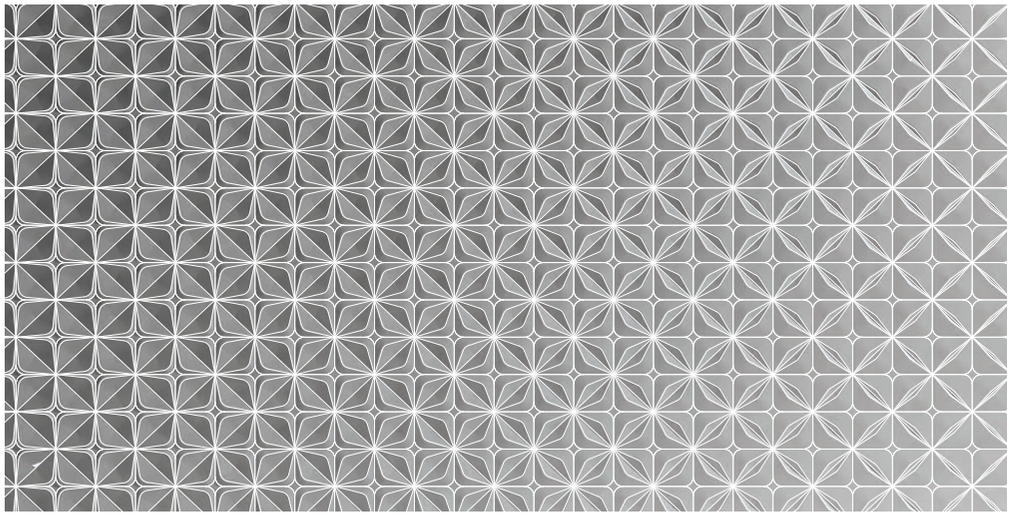
With a singular project aspect, and an integrated singular parametric model, a strategically important feature was the possibility for a non-specialist to take part in design refinement through direct modeling. [Contexts II: p.84, p.177]



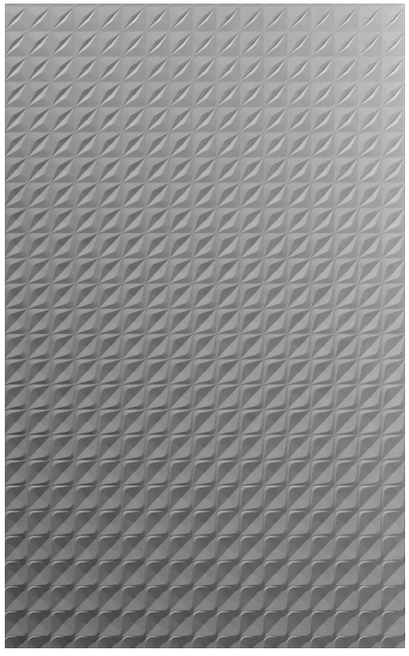
03 Primary parametric variation marked in blue, transforming from 'open' to 'closed' situation, Single units and symmetrical configuration with sets of four units creating a new pattern, parametric variation marked in blue.



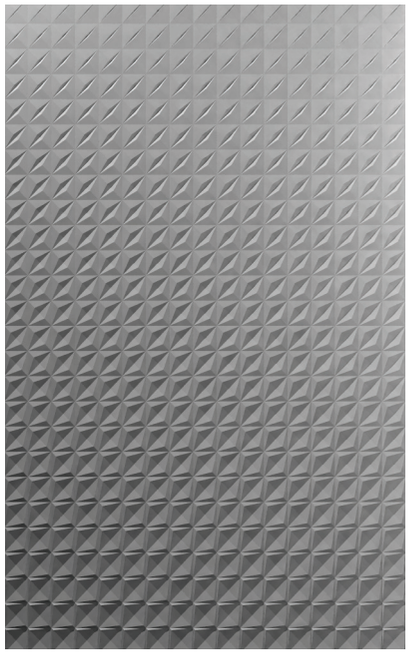
04 Gradual ornamental pattern distribution, assymetrical configuration



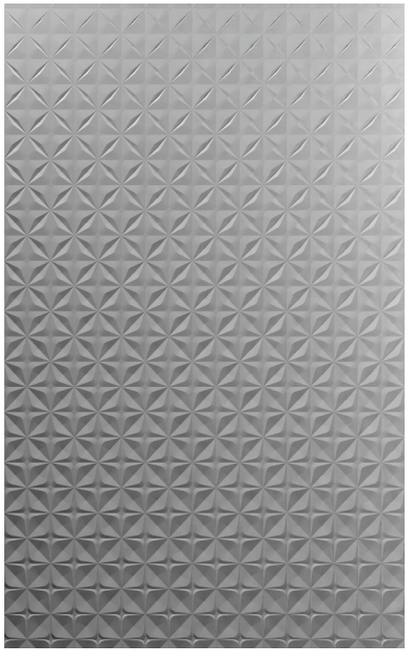
05 Transition from 'open'towards a 'closed' state, left to right, with no transformation in vertical direction



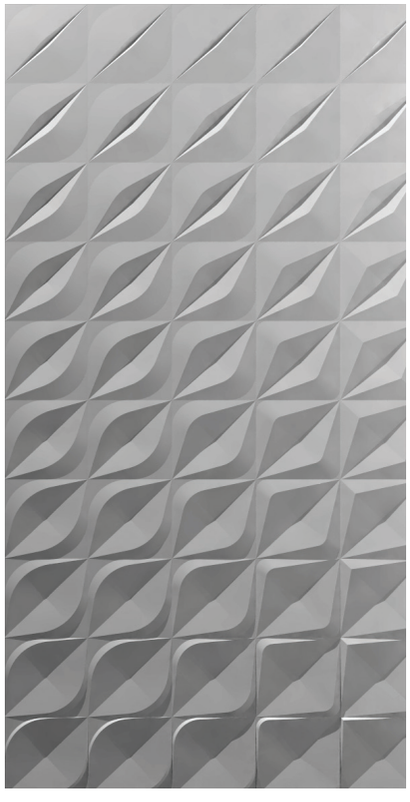
06 Asymmetrical pattern with curvature



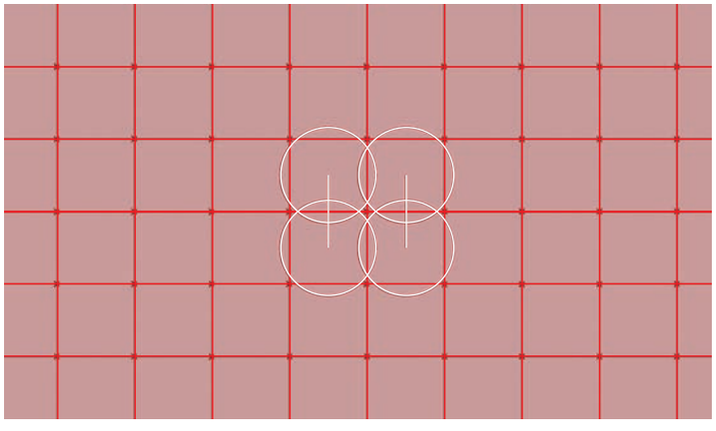
07 Asymmetrical pattern no curvature

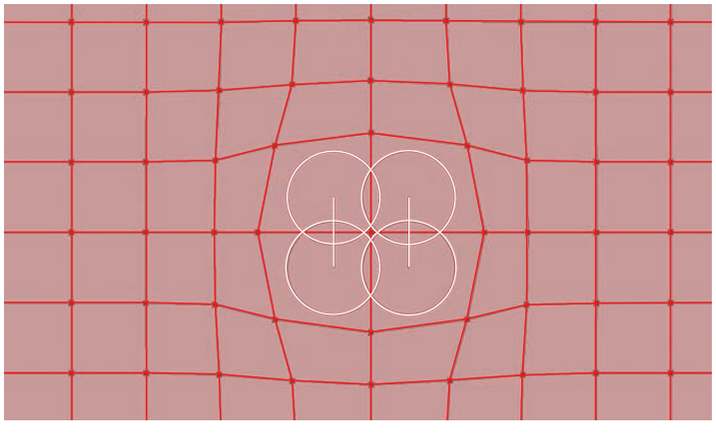


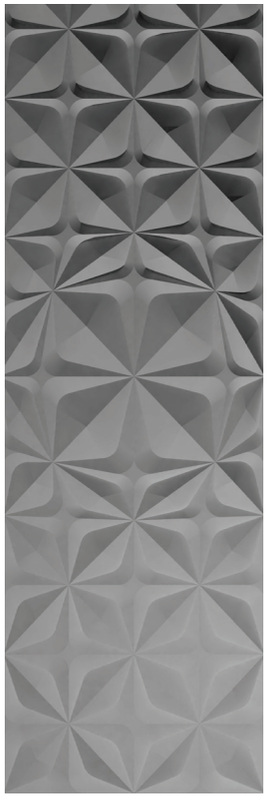
08 Symmetrical pattern with curvature



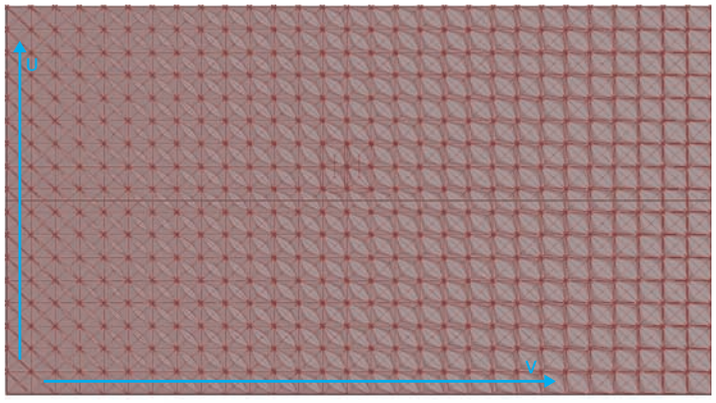
09 Gradual transformation of curvature (fillet) in horizontal , and aperture in vertical directions

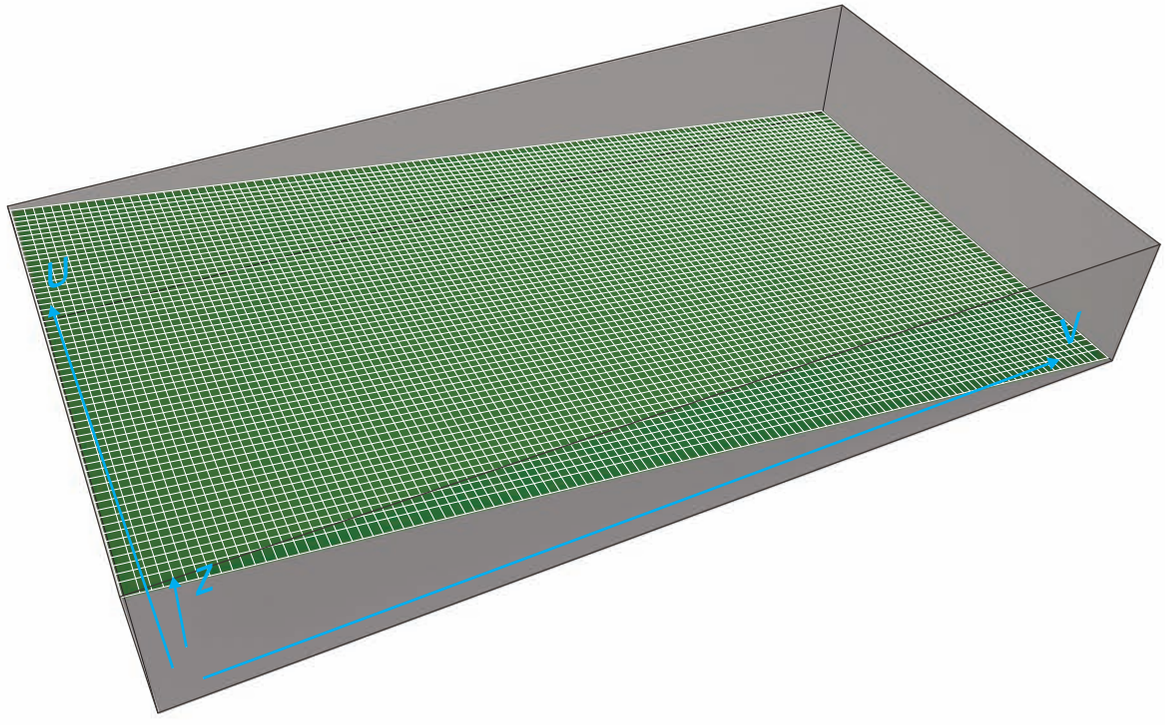


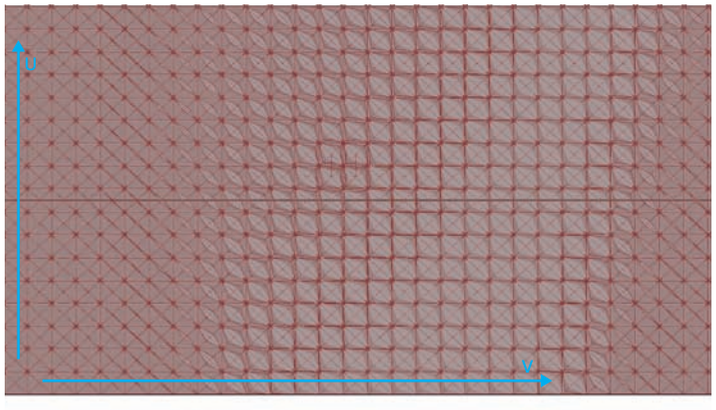




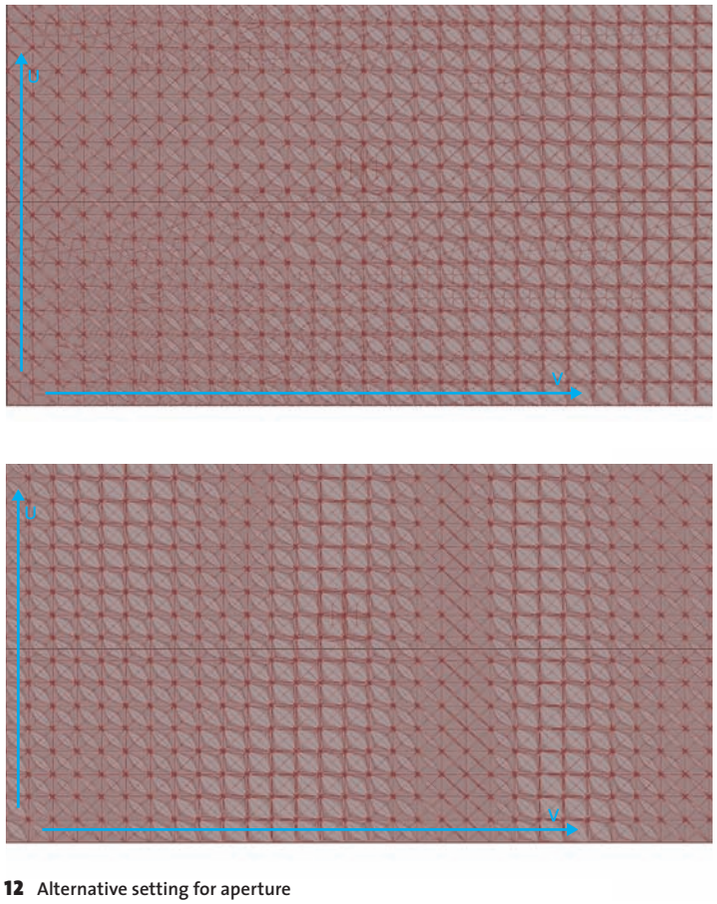
10 Generated ornament without and with activated repelling lines



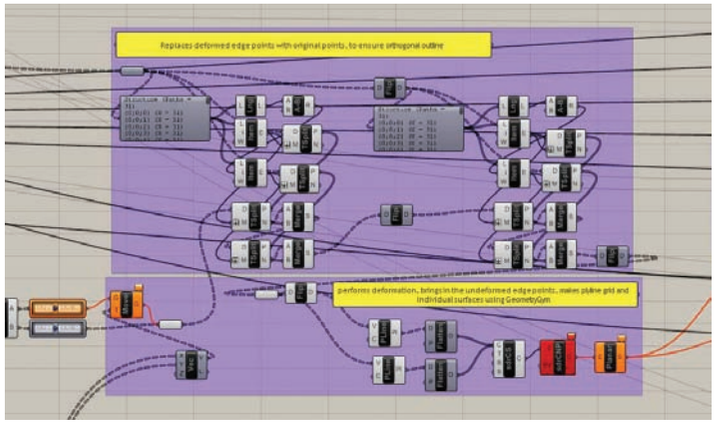


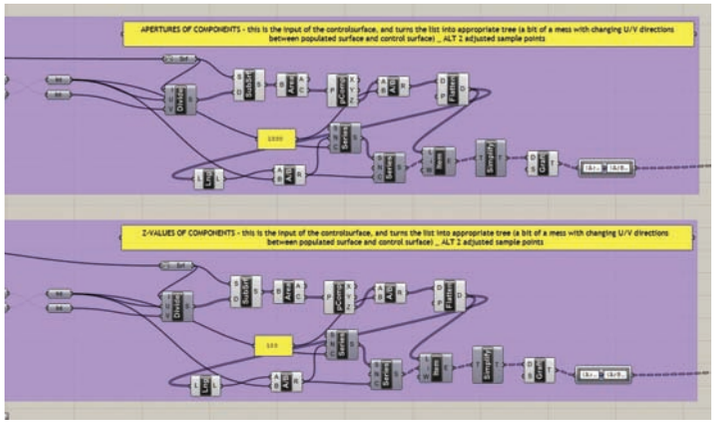


11 Control surfaces for aperture variance; uniform and non-uniform transformations, with resulting pattern effects



12 Alternative setting for aperture control surface with resulting pattern effects, and control surface applied for fillet control





13 Parametric definitions for grid deformation and control surface application

Reframe

Jonas Runberger, Dsearch, White arkitekter 2011

Developed as a parallel study to a competition entry, the 'Reframe' project is a self-supported paneling system in which views and light filtration can be globally controlled. The specific case of a stair well, design schematically within the competition proposal, set conditions in respect to light directions and dimensions, but the system could be re-deployed at different scales. In addition to the proposal of a new design trope – the stepped configuration of triangular panels – the project included an interface for manipulation of non-specialists through direct modeling.

Design Narrative

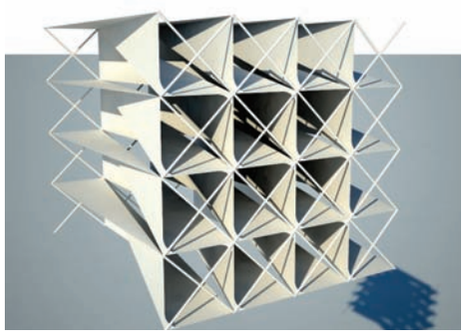
Reframe was an adaptable paneling system for deep partitions, based on a triangulated self-supported structure. The structural integrity was achieved through a combination of rigid triangular panels of MDF or cross laminated wood and a system of tension cables [01]. The depth of the partition was variable; a specific partition may have different thickness at local areas, which allowed for a variation of light admission and visual connectivity through the partition. The system was developed as a generic design that could be deployed in different contexts, and variation was achieved through the two framework surfaces that controlled its global deformation (through overall form) and local distribution of size, position and angles of individual panels. The design of the panels followed a step-like configuration, in which panels were connected diagonally across the surface of the partition [02 + 03]. Due to this configuration, the panels did not achieve structural stability on their own, and required a cable net for cross bracing. However, this allowed a larger partition to be divided in strips that could be easily handled. Depending on the scale and size of the individual panels, they could be fabricated as combined components with etched fold lines [03] or as individual units with a joint.

The system was applied to a particular part of a competition entry for the extension of the Serlachius Art Museum in Mänta-Vilppula, Finland. A conceptual design for a stairwell, a key feature of the proposal, was used to contextualize the system and explore its potential. The scheme was based on a staircase connecting the two main floors and a skylight, in which light was meant to fall extensively into the upper level, but in a controlled way to the lower [06]. The concept featured a double stair in two directions (as part of the overall organization of movement in the building) and an articulated partition to catch and convey light as well as divide the space of the stairwell in two parts [04 + 05]. For the competition entry the design remained quite abstract, and the partition was represented as a smooth reflective surface with two kinks [07]. The Reframe system was deployed after the entry was submitted, partly in anticipation of a commission, but primarily as an opportunity to explore and further develop its potential.

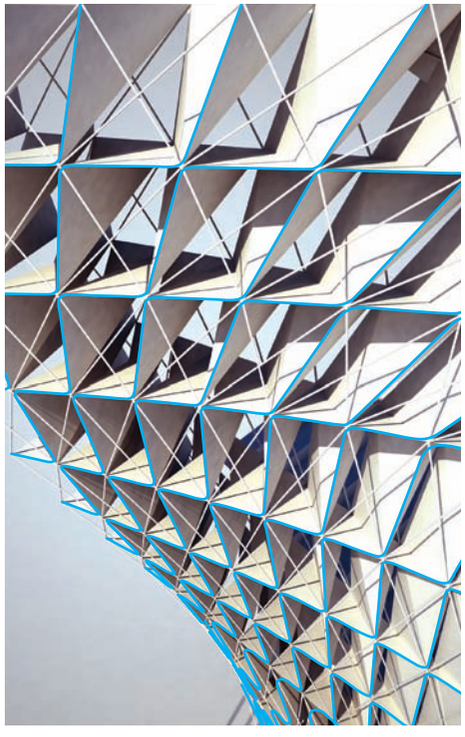
A main characteristic of the system is its differentiation in regards to light admission and see-through views, and the same system would seem solid from certain angles and quite transparent from others [10]. In the default configuration the two framework surfaces could be identical at a set distance, generating a deep truss-like structure and a corresponding template for fabrication. By moving a control point of one of the framework surfaces a differentiation of the thickness would be achieved. By moving the corresponding control points of both framework surfaces in the same direction, the panel system deforms with a uniform thickness, [11]. A distortion of one framework surface within the plane of that surface would provide apertures in that region of the system [12].

The overall configuration of the system as applied in this case, added a landing midway that also connects the two stairs through an aperture in the partition [08]. The overall form of the partition was given a variable depth, and the two framework surfaces were configured to provide a smooth transition from top to bottom [09]. A parametric model was based on two double layered surfaces as framework for the system, which also provided the opportunity to control the aperture placed at the intermediate landing. The angles of the framework surfaces could be controlled, with an additional angle control that allowed for differentiation of depth [13]. Overall manipulation of the framework surfaces could be done without the application of the components of the panel system for faster feedback [13 + 14], but at any given configuration the components could be applied to check how they would deform to the framework [15]. Key parametric definitions looked at the overall control of the framework surfaces in relation to any given slab opening, the alteration of the partition opening by manipulating both sets of framework surfaces in a sym metrical fashion, the allocation of panels over the framework including adaption to different light conditions and expectations, and the association of the staircase to the framework surfaces. The design was evaluated according to the overall form, as well as local expressions, while following the given footprint of the opening in the slab between the floors [09].

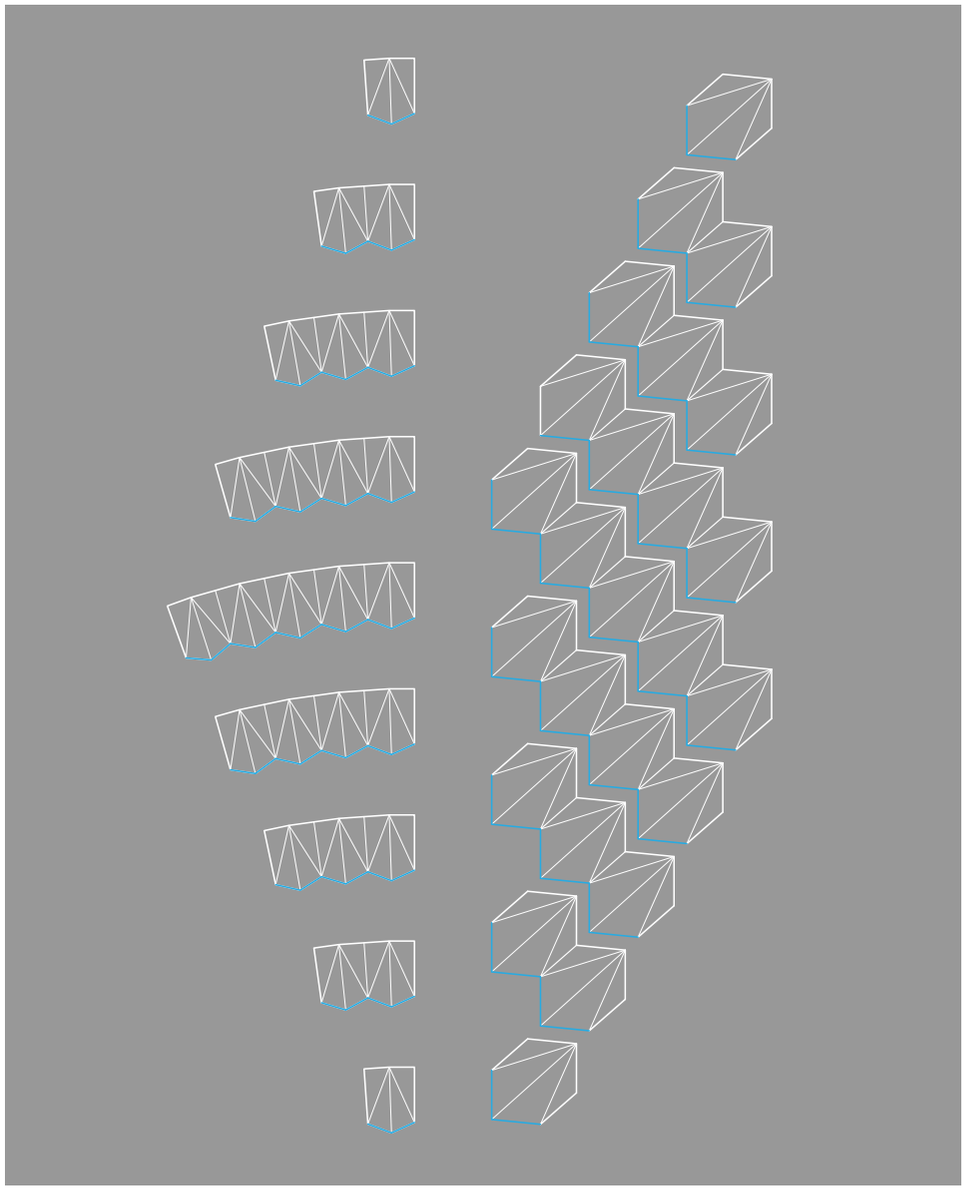
This geometrical principle provides the particular performance in regards to light and sight lines, and it is controlled directly by the configuration of the framework surfaces rather than by additional control surfaces. In this way, Reform becomes a generic paneling system that easily can be re-fitted to a number of different conditions, and a parametric response to strategies and concepts that define those conditions.



01 Reframe system sample with tension cables



02 Reframe system strips of material consistency marked in cyan



03 Fabrication and exploded view of assembled panel, diagonal consistency between panels in cyan

Digital design Techniques

The project was completely developed as a parametric system, enabling a global variation which in turn controlled component variations and staircase design, as well as generated fabrication drawings. In addition, the staircase could be further controlled in regards to step size and number of steps. [Contexts II: p.22, p.27]

Architectural Performance

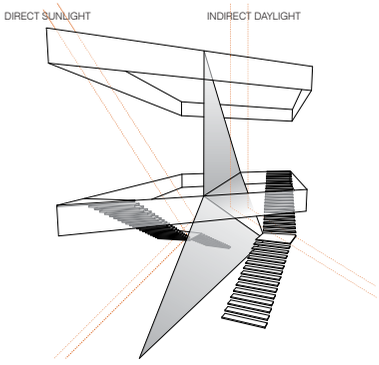
The Reframe system integrated structural performance, in the sense that it is self supported, with light filtering capacities and spatial articulation. [Contexts II: p.38, p.40]

Speculative Design Aspects

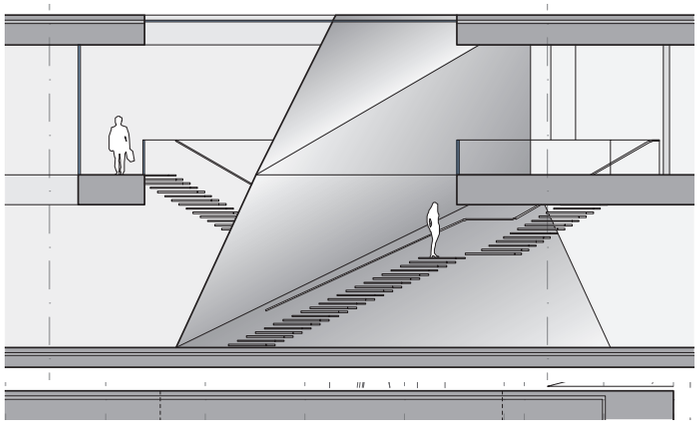
Speculative aspects of the projects were present in the parallel development (in regards to the competition project).
[Contexts II: p.60, p.61]

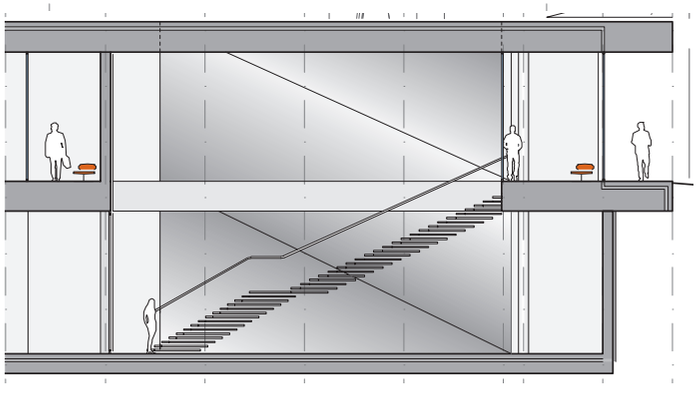
Digital Design Strategies

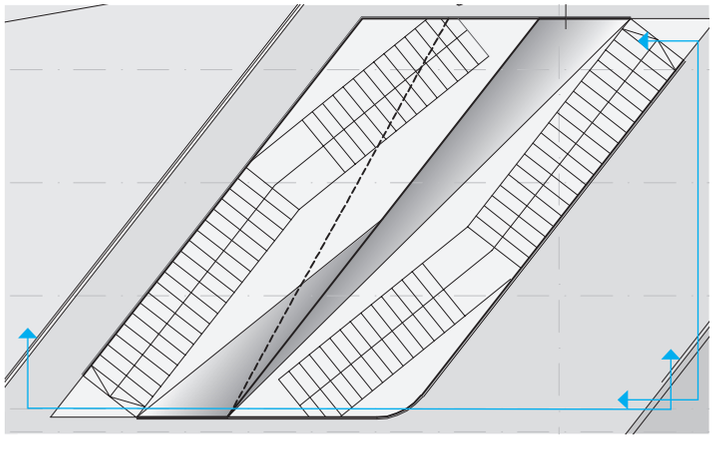
The project combines two project aspects into one through the integration of a staircase and a light controlling partition. Both were developed in a single parametric model. The types of engagements included formal design development and planning for fabrication, with the potential for further development in daylight analysis.
[Contexts II: p.84, p.177]



04 Concept of light distribution from competition entry

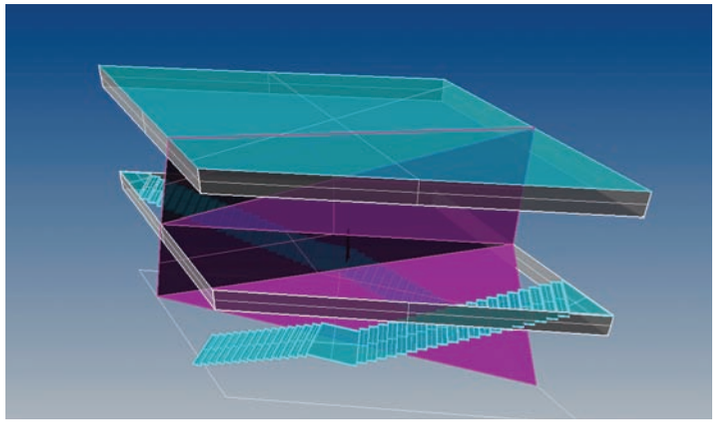


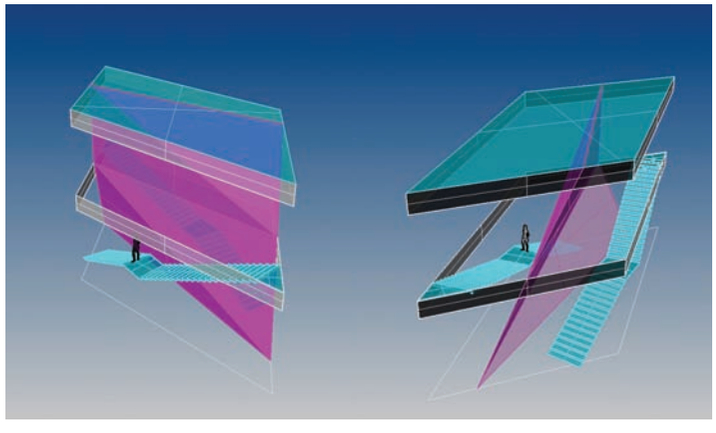




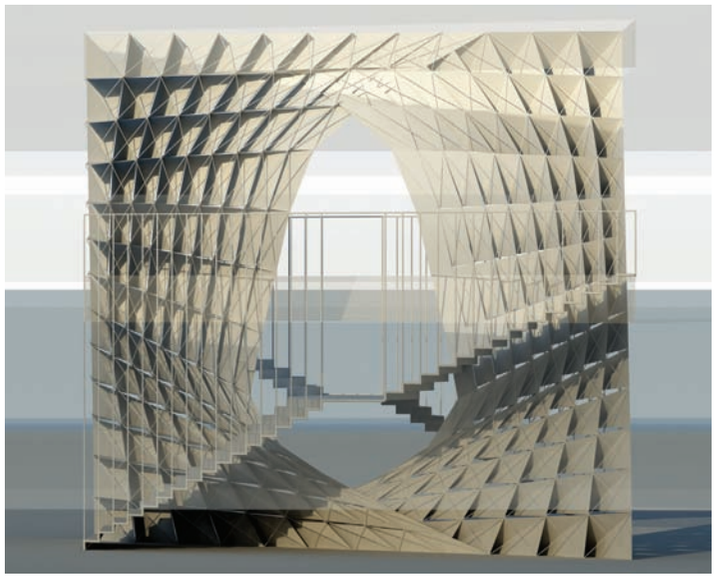
05 Plan and elevation of s ample study

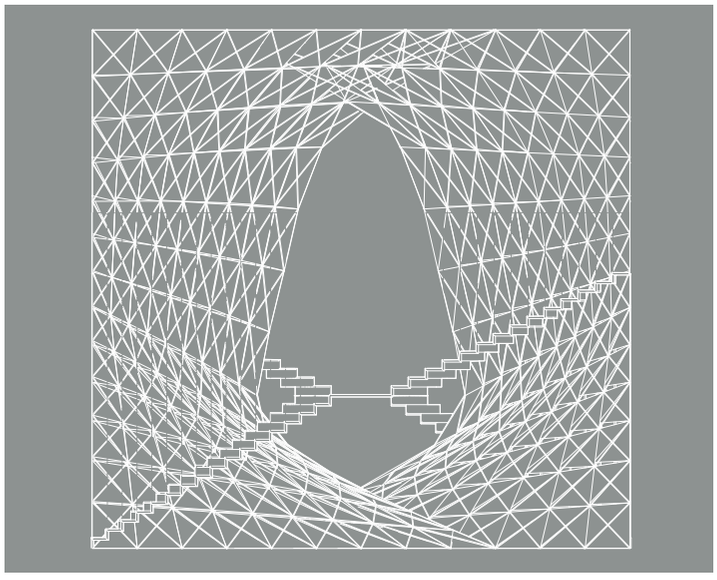
06 Rendering of stair from competition entry, upper level



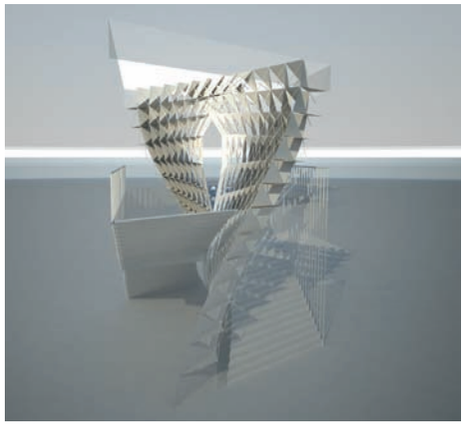


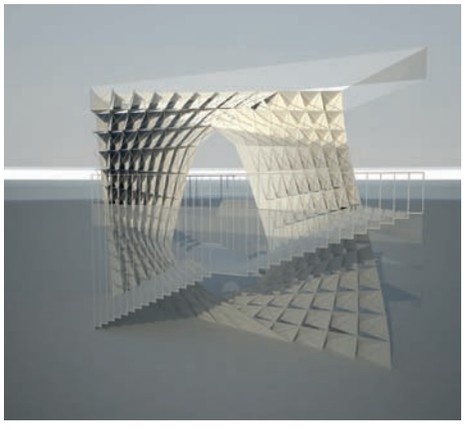
07 Schematic model of stair from competition entry

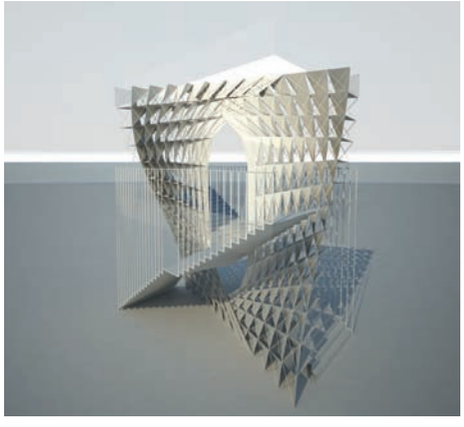


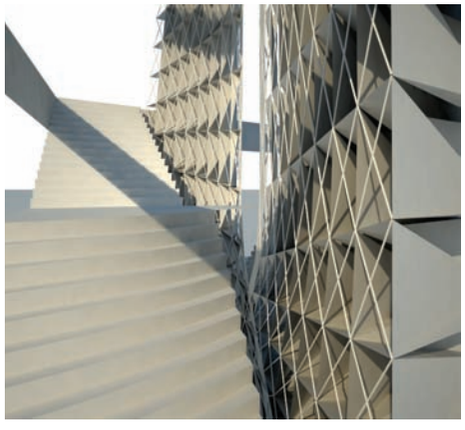


08 Elevations of Reframe system applied

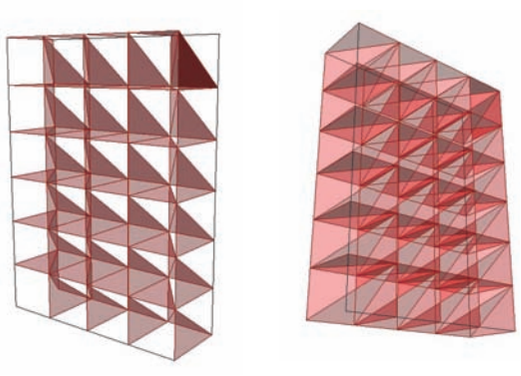




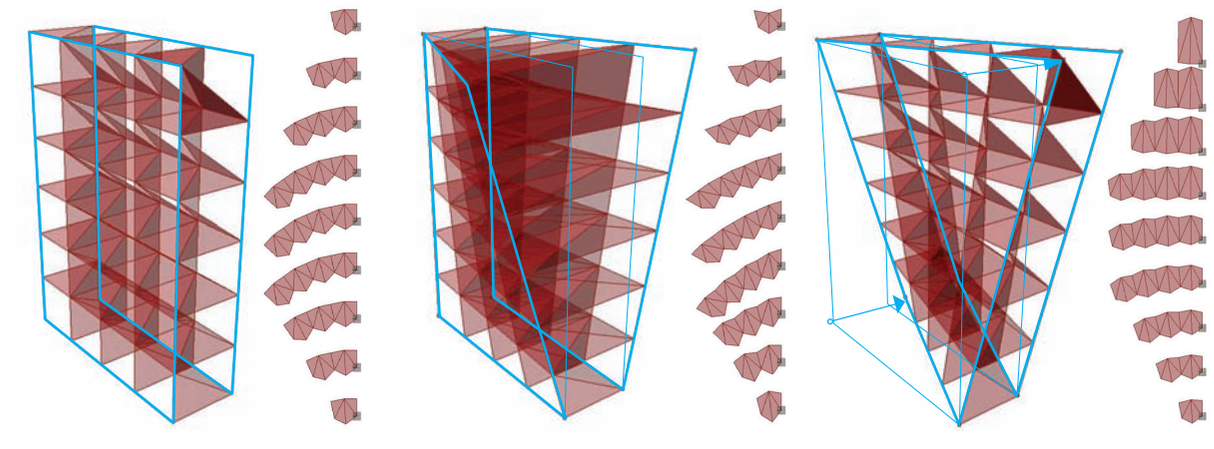




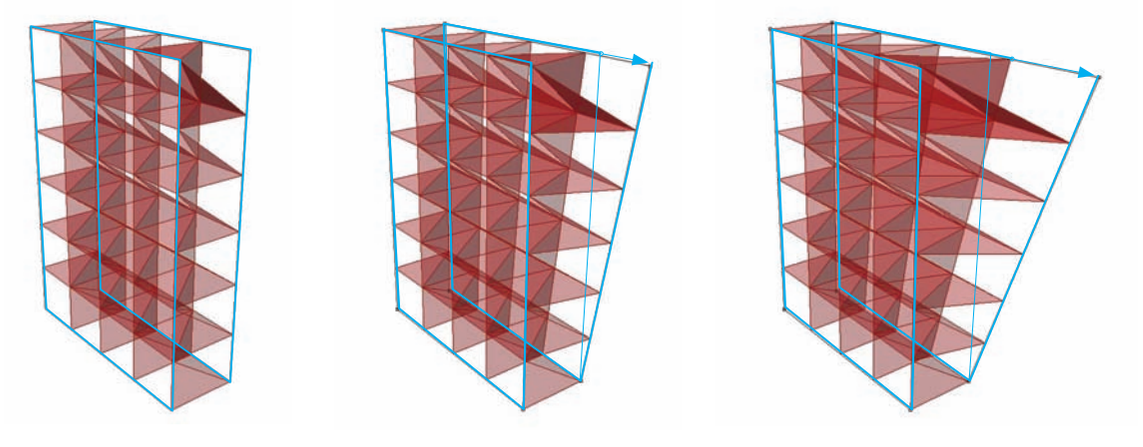
09 Selected views of Reframe system applied



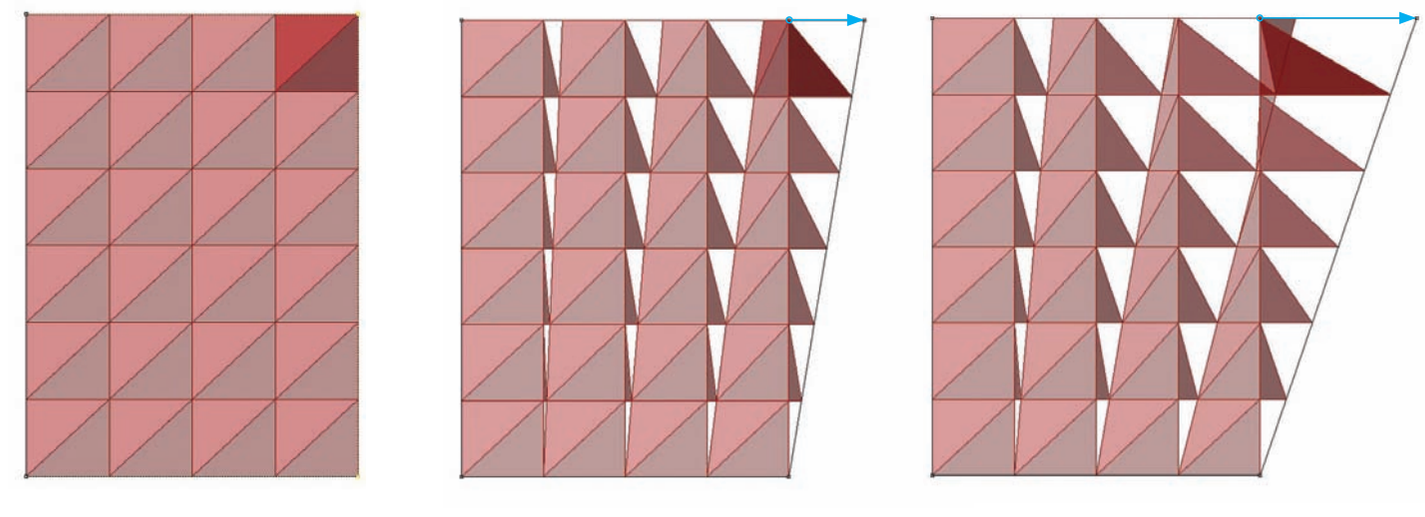
10 Differentiation of visual connection in uniform system configuration depending on viewpoint

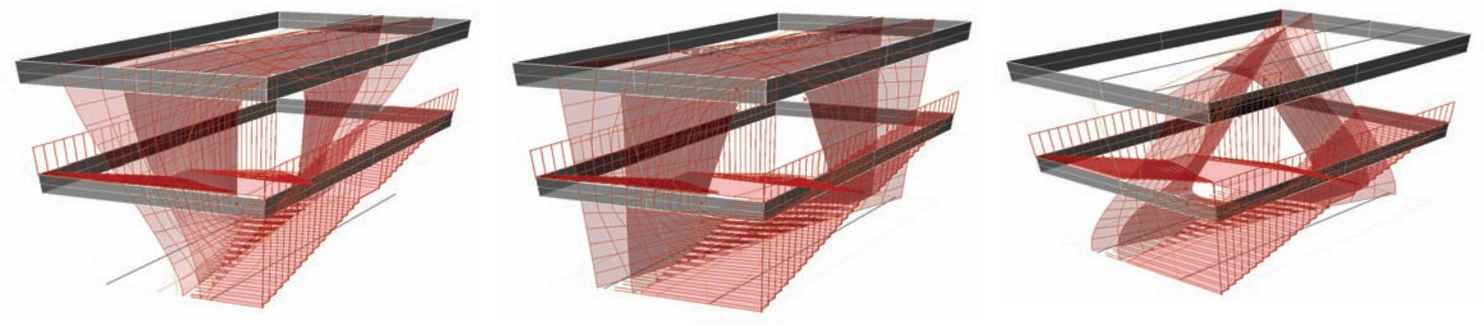


11 Deformation of framework surfacesand corresponding fabrication plan

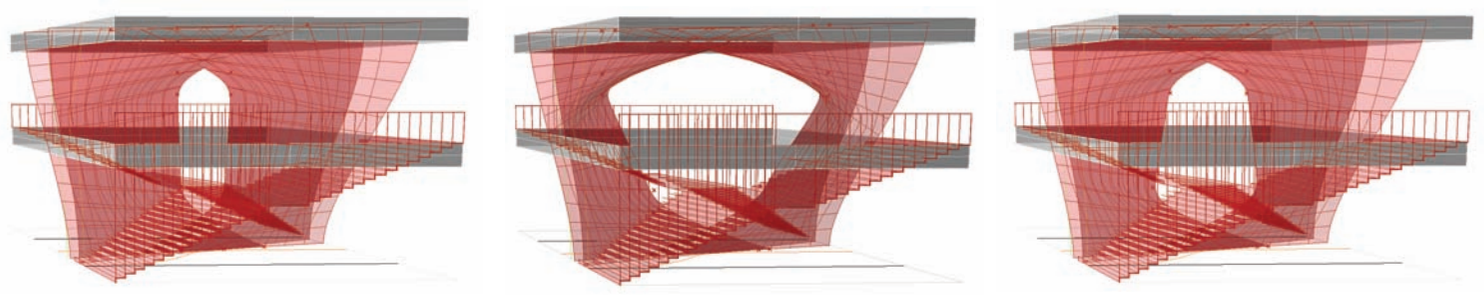


12 Deformation of framework surfaces and corresponding changes in visual connection

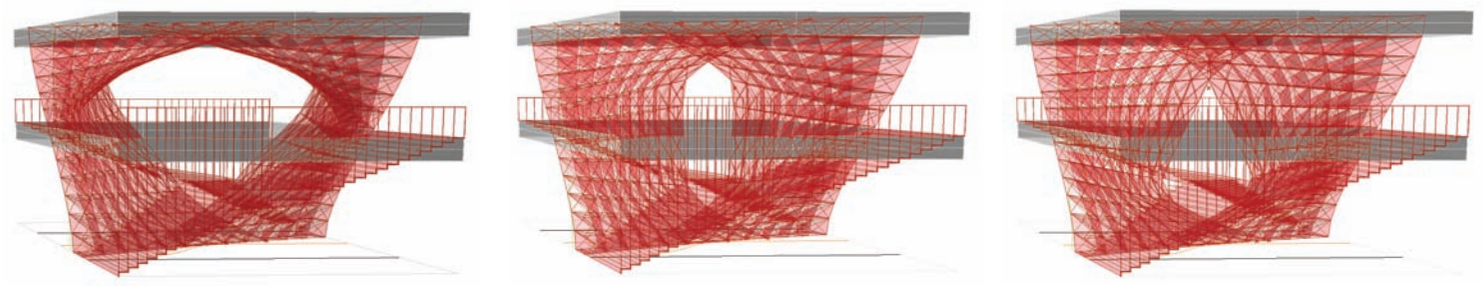




13 Parametric global variation of framework surfaces



14 Parametric local variation of framework surfaces to alter central opening



15 Parametric variation with Reframe components applied

Quality Globe Hotel

Jonas Runberger, Dsearch, White arkitekter 2011

Developed in response to the need for further development of an existing design concept for interior cladding, the 'Quality Globe Hotel' project entailed the development of a project-specific formal design concept, design system and a design trope. The design principle was based on a sampling of formal references at conceptual level, informed by geometrical definitions and fabrication constraints. The developed parametric model allowed collaboration between specialists and non-specialists through direct modeling and refinement of the parametric model.

Design narrative

The parametric design system was developed as a study within the Quality Globe Hotel project, a project involving an extension to an existing hotel in southern part of central Stockholm [01 + 02]. As part of an overall mood map for the project, the two formal principles of striated and gem-like formal aspects was defined as common themes [03]. The development of a parametric system was limited to the envelope of a conference room suspended in an atrium over the entrance and foyer areas. The external volume of the conference room would be visible from several directions; from the lower foyer level acting as the ceiling of the foyer [04 + 05] , from four directions on the upper foyer level [04 + 06], and from above from an elevated passageway and hotel rooms facing the foyer [06].

The project already had a basic design for a patterned cladding loosely based on the formal theme, repeated across the surface [07]. The first step of digital development was conducted through an initial short workshop with the design team, based on the formal theme as well as a number of reference projects. During this workshop, a formal trajectory was defined by sampling and editing two strong formal approaches; a laminated approach with multiple lamella systems, and a diamond shaped principle of folding [08]. The system of lamellas would be set up in a parallel fashion to provide repetition through equal distances between lamellas, and variation through the overall form. The diamond shaped components would add local variation and definition, to provide spatial definition (in the foyer ceiling where they would articulate the reception and bar) or localized light features to articulate larger areas.

The overall form of the cladding was defined as a free-formed envelope, and the parametric system developed should be applicable to a generic overall form. A basic parametric system for the parametric generation of lamellas was developed, in which a control line would define the direction of the parallel lamellas. An equal distance set of planes were propagated across each line, and the intersecting lines between these planes and the framework surface would define the lamellas [09]. By moving one control point of the control line, the direction of the lamella system would be altered, providing a basic interface for a non specialist. Each lamella system would be placed on its individual framework system and be based on individual control lines, allowing two adjacent systems to be placed in different directions [10]. The diamond component was developed on the basis of the generated lamellas, and at default deployment they would follow the lamella direction, and automatically remove lamellas to avoid intersections [11]. The components could also be individually controlled in terms of their dimensions [11 + 12]. Through direct modeling, the location of the diamond components could be coordinated with, the boundary between lamella systems [13].

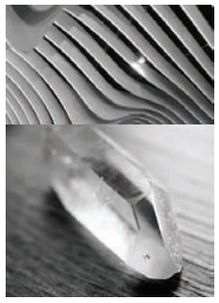
The two principles of parallel lamellas and diamond components would in the project implementation be deployed over a number of framework surfaces. Using a deformed box as a basis, a series of investigations looked at how the overall envelope could be broken into regions for separate lamella directions. In the final iteration, the basic principle is that each side of the box primarily employs one direction, but the corners, even if rounded, was of particular concern. Each individual lamella system operates well on one surface, and could continue onto an adjacent, 90 degree shifted surface, but for the corner condition the system would need to be directed in 45 degrees towards the corner in order to avoid lamella sides to be too exposed. The solution was that each surface would drape over one corner, and its lamella direction would be directed towards this corner [14]. Since a box of six sides have eight corners, two surfaces need to be divided in order to drape two corners [19 + 20]. For each corner one surface would be draped, either from right left, top or bottom surfaces (for the lower corners) [15]. With lamella systems applied, it's apparent that the draped surfaces also benefit from being directed towards corners [16]. When deployed in the context of the hotel foyer, particular views could be identified such as top view [17], upper level view [18], bottom views over corner and the foyer below the conference space [22]. Key areas would feature diamond components, in order to articulate passages or for spatial effect [21 + 22].

Digital design Techniques

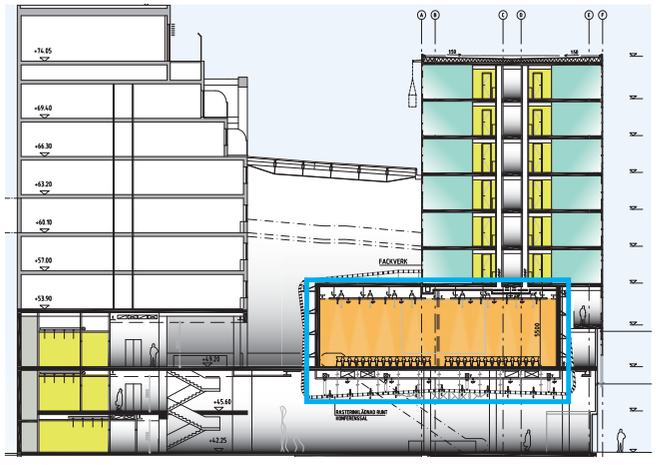
The project entailed the development of two related parametric systems both based on a volume created through direct modeling. A non-specialist could take part in the development either through direct modeling manipulation of the base volume and lines controlling lamella direction, or adjusting numerical input controlling lamella width and diamond component dimensions.
[Contexts II: p.22, p.28]

01 External view of hotel addition

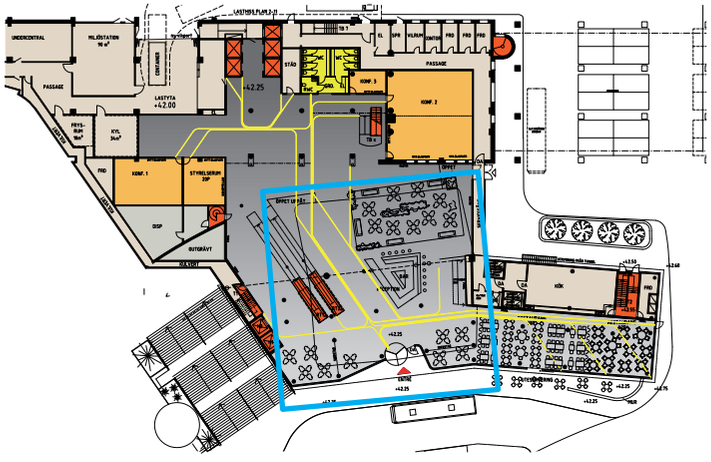
02 Location between the old and new arenas



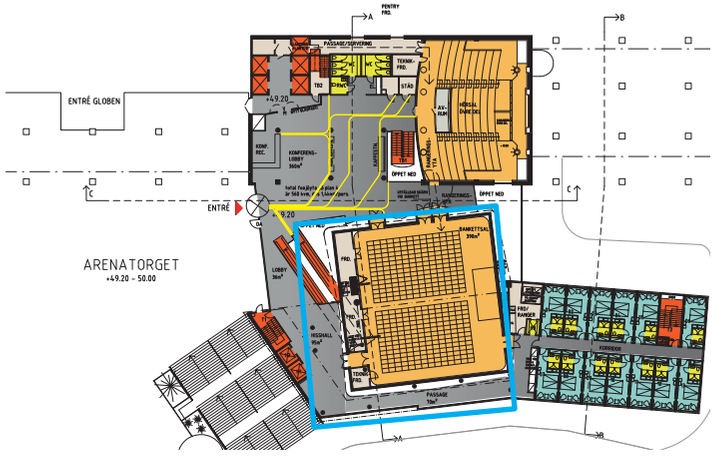
03 Formal references of striated lamellas and crystal structures



04 Cross section of atrium, conference room in cyan



05 Lower foyer level, conference room in cyan



06 Lower foyer level, conference room in cyan

Architectural Performance

The parametric modeling approach enabled specialist and non-specialist collaboration. The formal principles, and the parametric systems that enabled it, were developed to drape an overall form in sections, with controlled intersections between different configurations. This in turn created local continuous patterns that could be reconfigured [Contexts II: p.38, p.40]

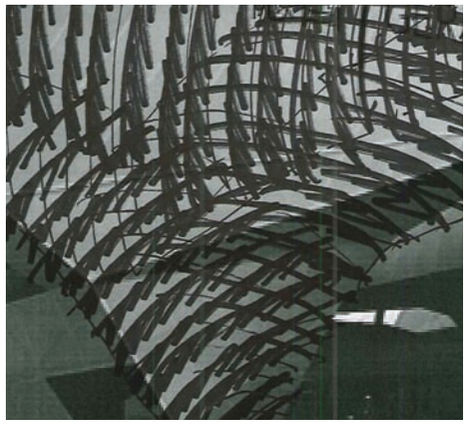
Speculative Design Aspects

Developed as part of the early stages of a more comprehensive architectural project, the development of non-specialist interfaces can be regarded as initial speculations on future practice.
[Contexts II: p.60]

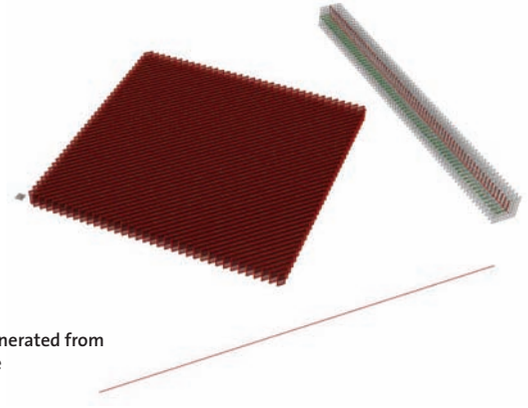
Digital Design Strategies

An important strategic condition for the development was the possibility for non-specialists to engage with the model. With a well defined project aspect, the formal concept could be developed in a focused way in which several design issues, such as interfaces between different systems in the corners of the main volume, could be developed through direct modeling. [Contexts II: p.84, p.177]

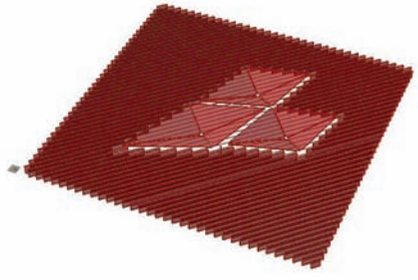
07 Original basic envelope concept



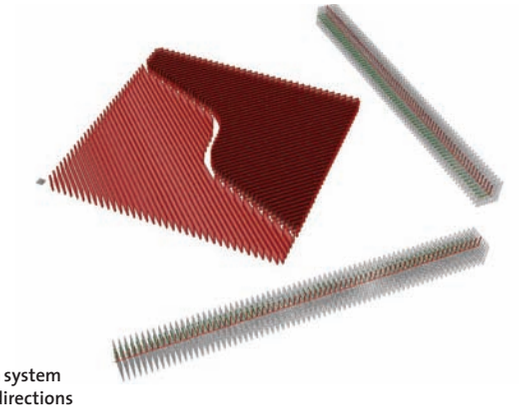
08 Sampled and edited references



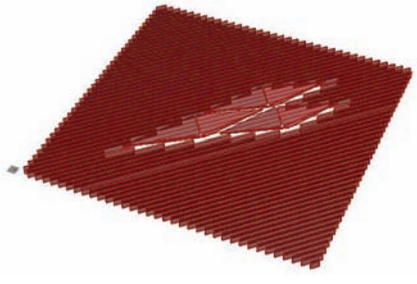
09 Lamella generated from control line



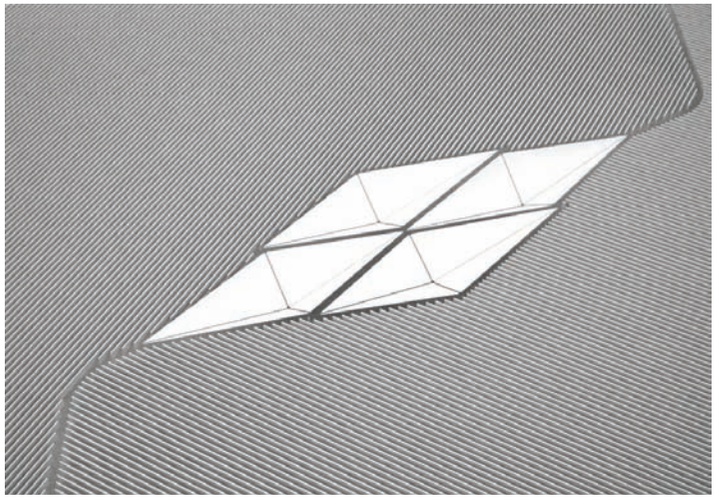
11 Inserted Diamond components, thick configuration

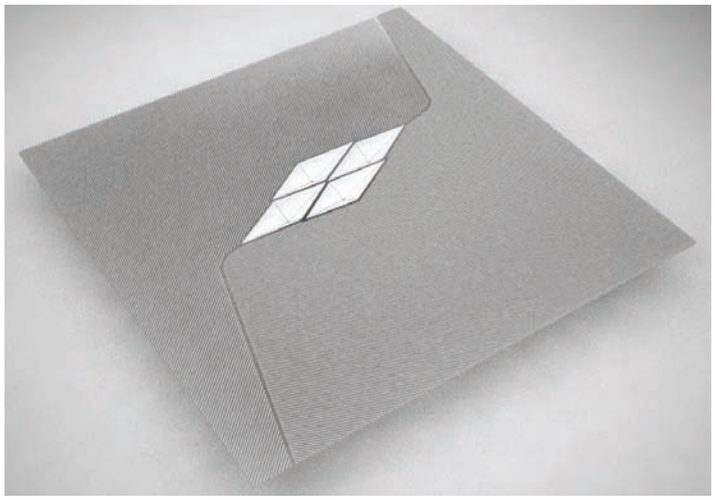


10 Double lamella system with separate directions

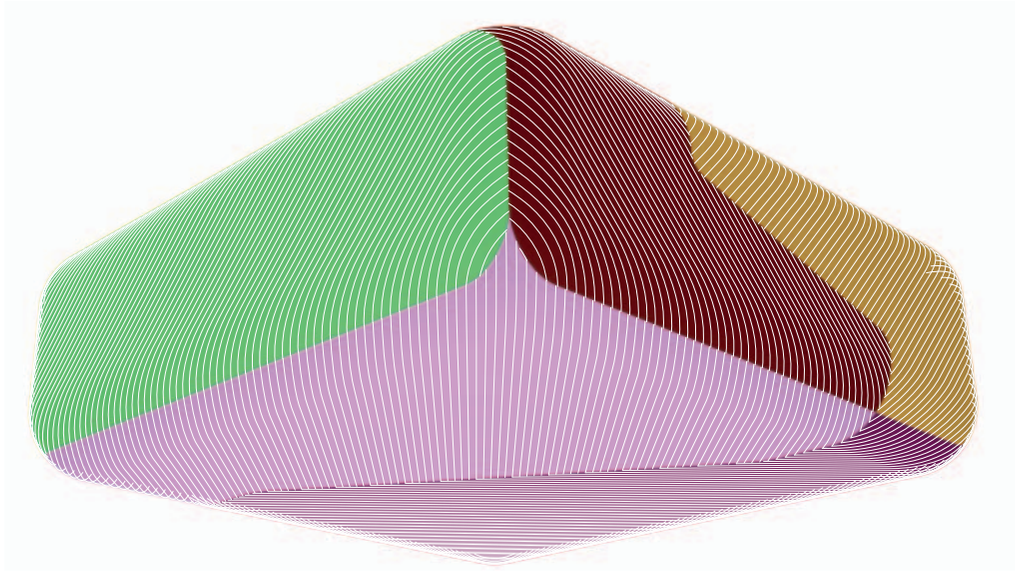


12 Inserted Diamond components, thin configuration

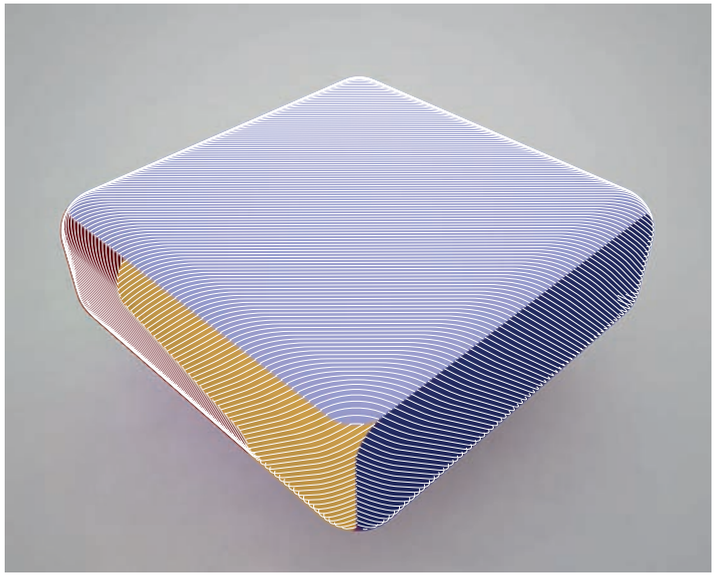


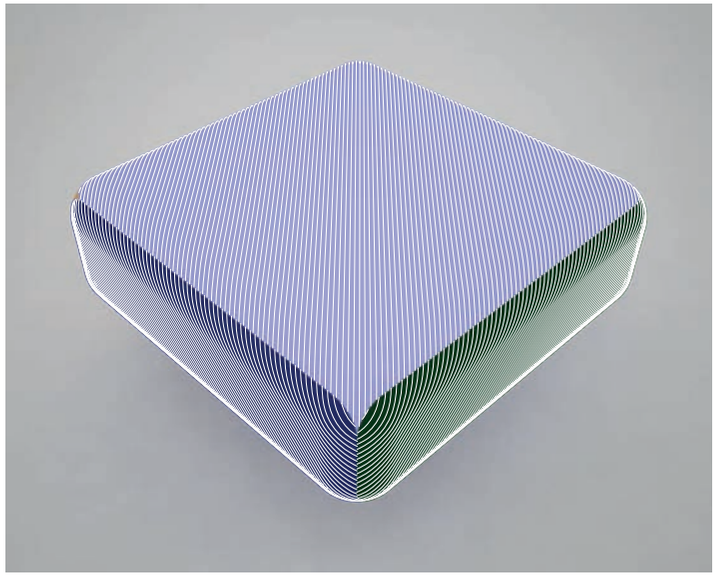


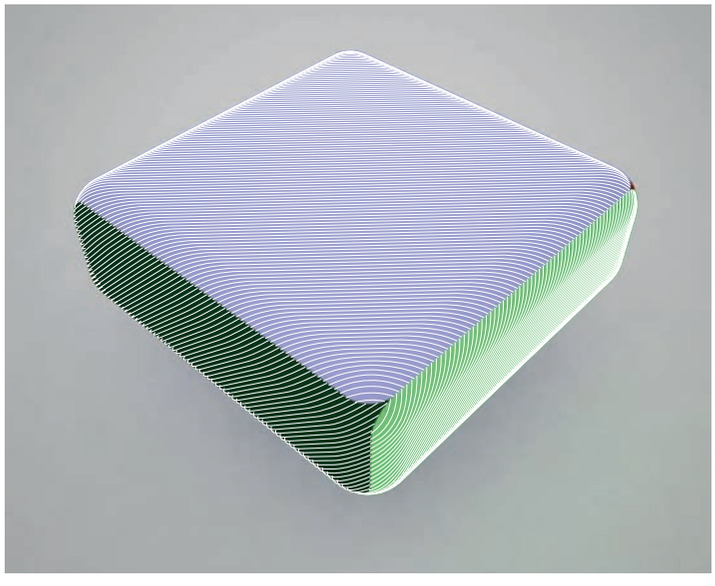
13 Sample surface with two lamella systems and four diamond components applied

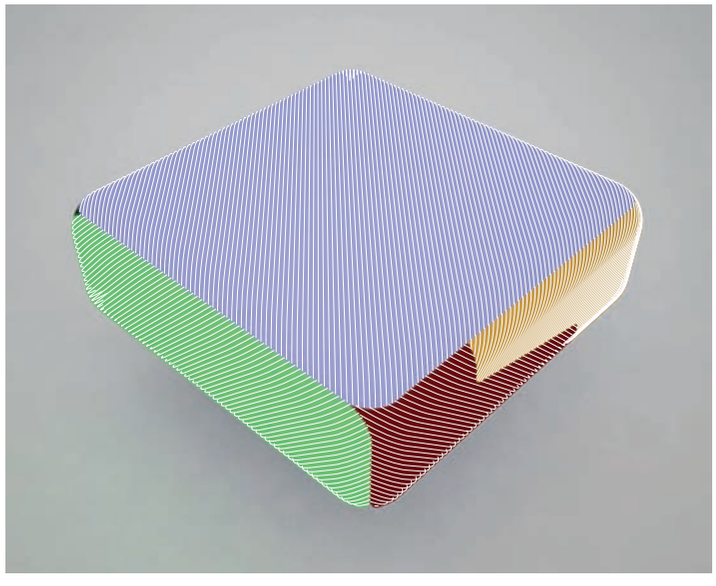


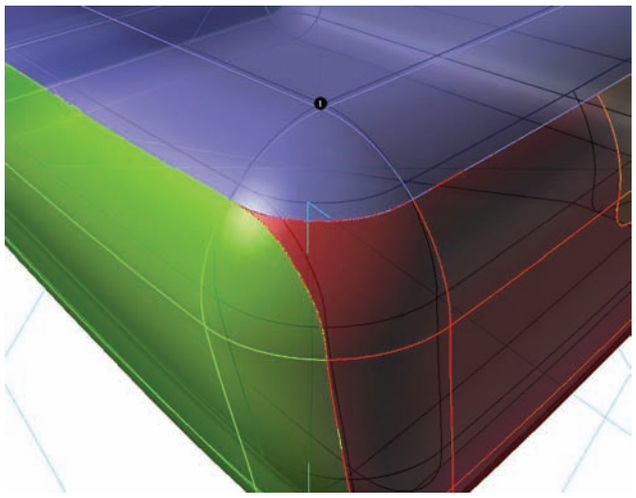
14 Studies of borders between lamella systems, and corner solution

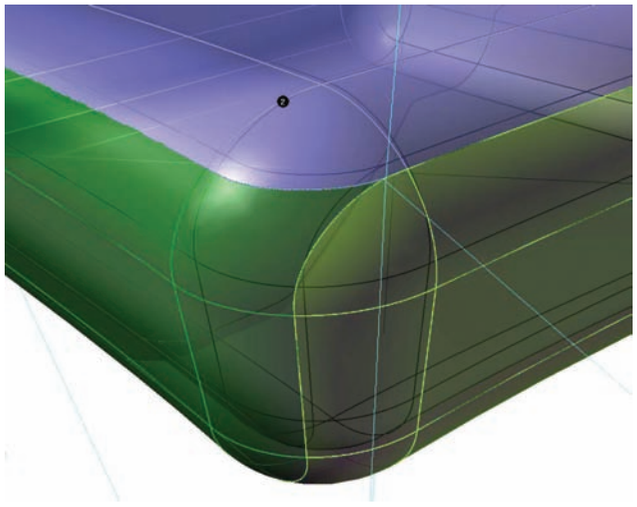


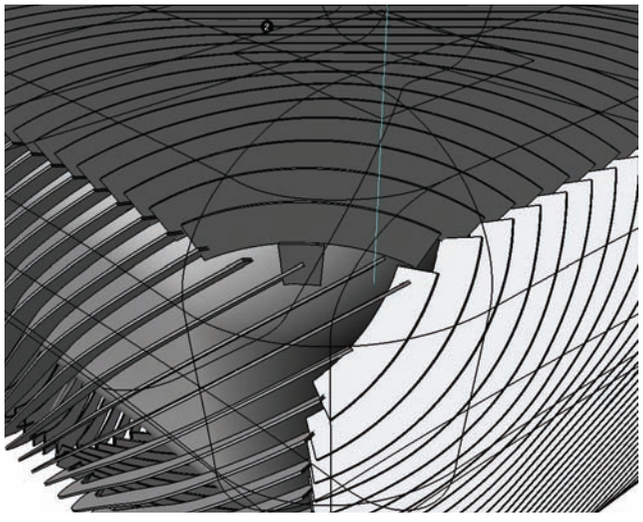


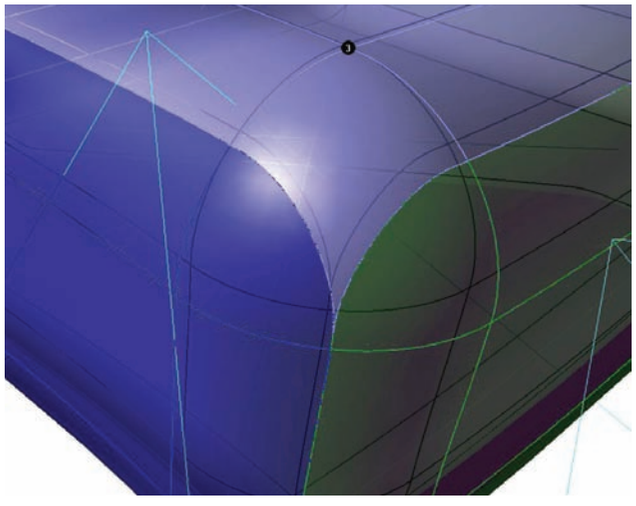


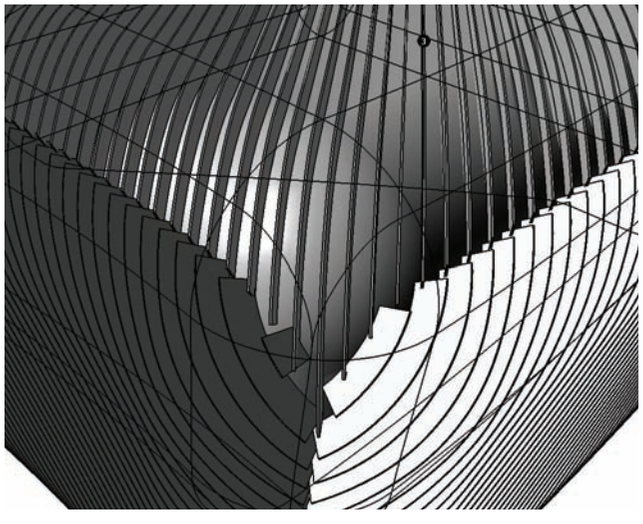






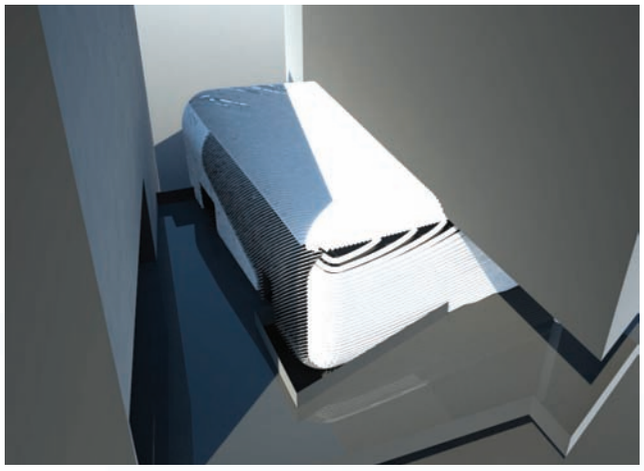




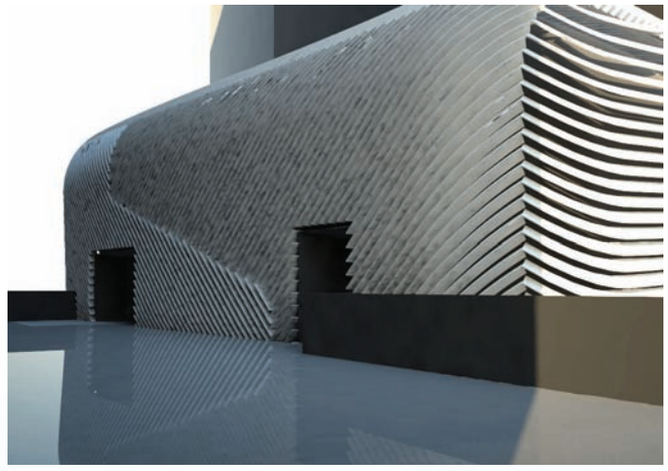


15 Alternate surface olutions for corners

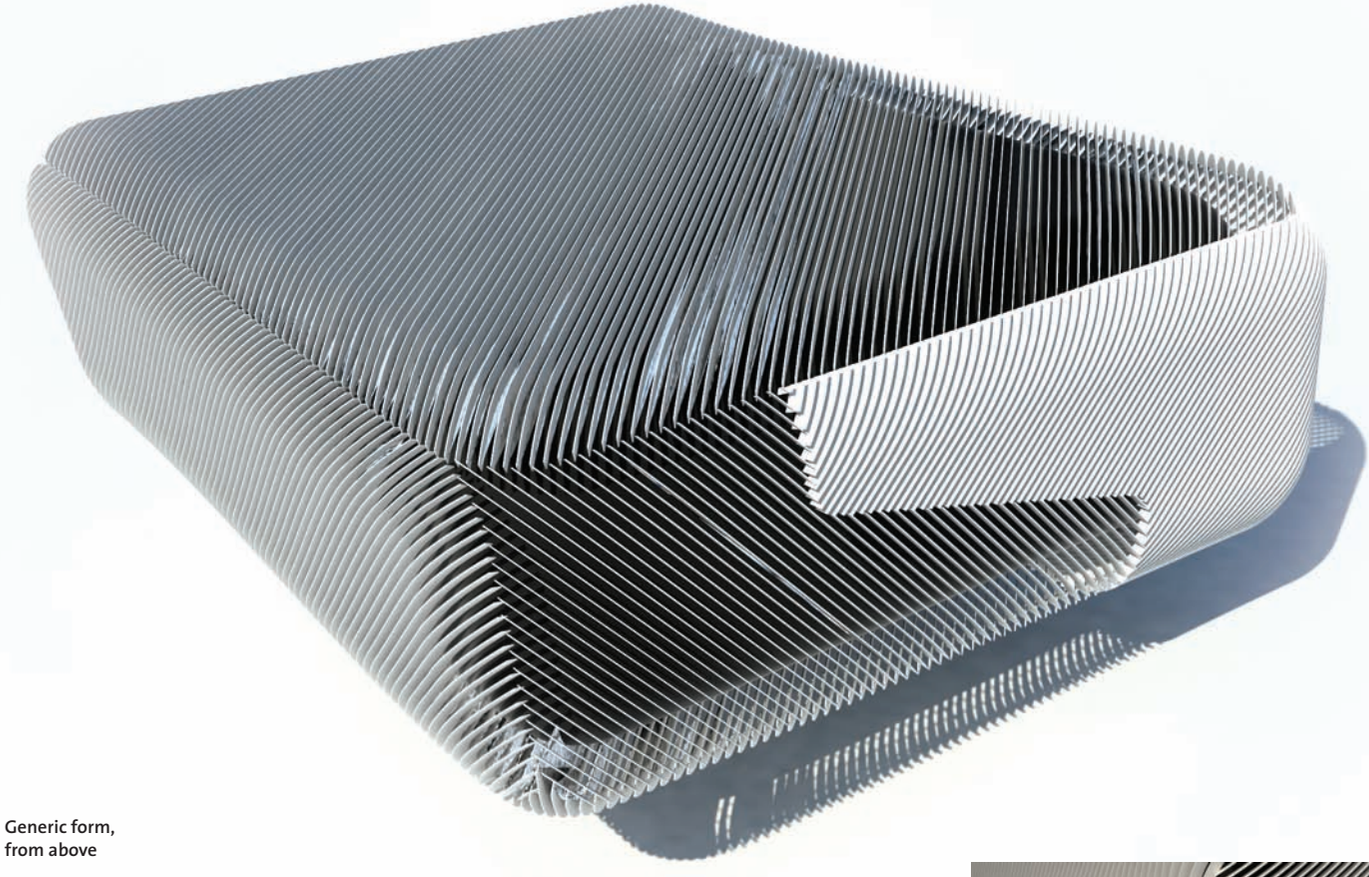
16 Deployed lamellas, top version preferable



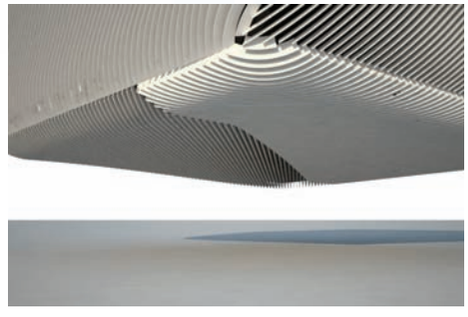
17 Study set in context, from above



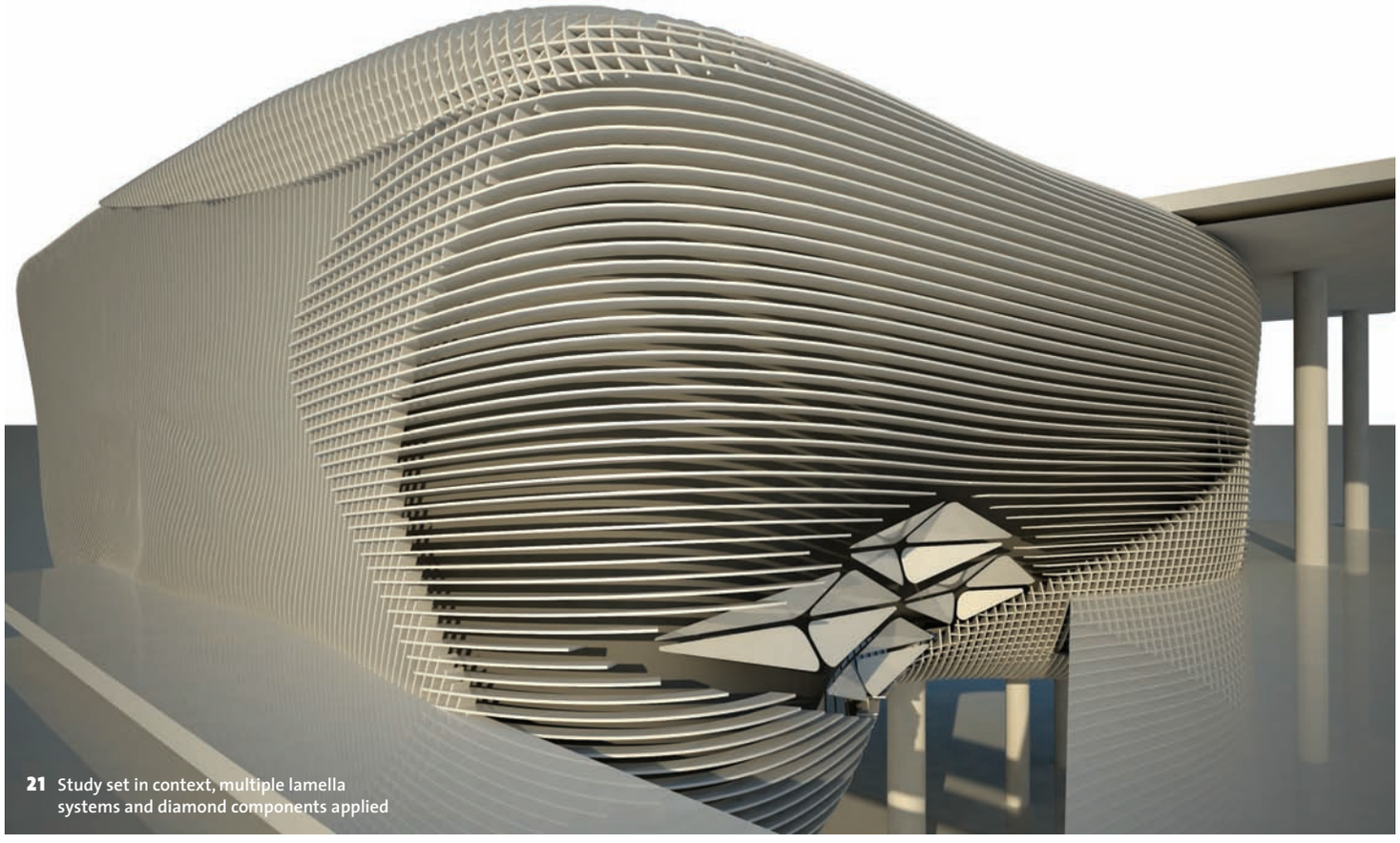
18 Study set in context, from upper level



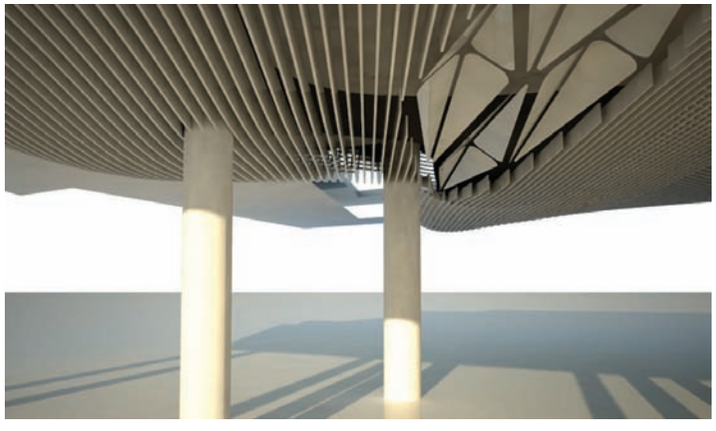
19 Generic form, from above

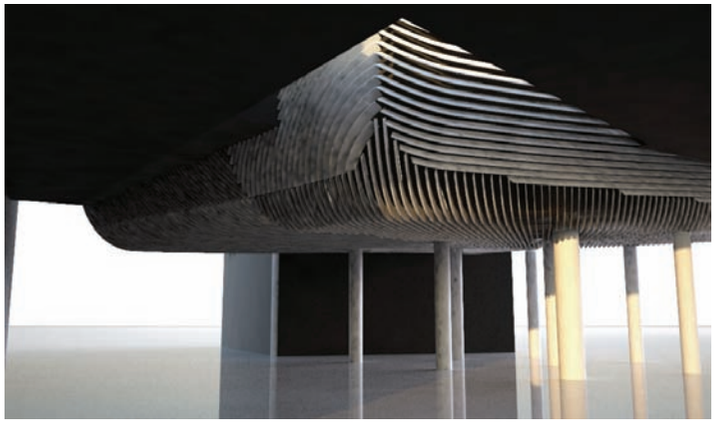


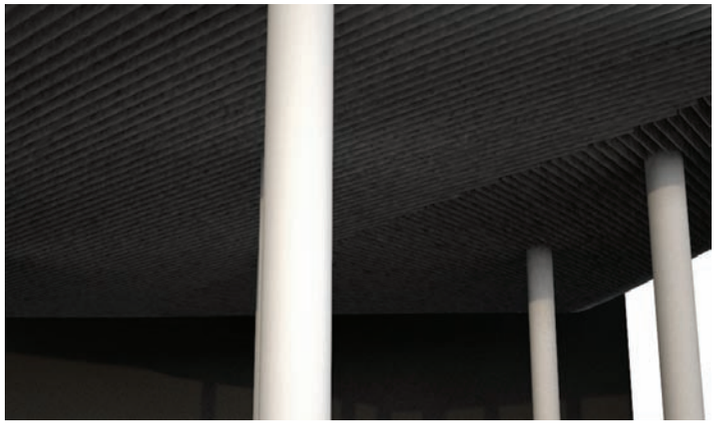
20 Generic form, from below



21 Study set in context, multiple lamella systems and diamond components applied







22 Study set in context, from below

Fictional References

The Colors of Mars[1]

"The point is not to make another Earth. Not another Alaska or Tibet, not a Vermont nor a Venice, not even an Antarctica. The point is to make something new and strange, something Martian.
In a sense our intentions don't even matter. Even if we try to make another Siberia or Sahara, it won't work. Evolution won't allow it, and at its heart this is an evolutionary process, an endeavor driven at a level below intention, as when life made its first miracle leap out of matter, or when it crawled out of the sea onto land.
Again we struggle in the matrix of a new world. Of course all the genetic templates for our new biota are Terran; the minds designing them are Terran; but the terrain is Martian. And terrain is a powerful genetic engineer, determining what flourishes and what doesn't, pushing along progressive differentiation, and thus the evolution of new species. And as the generations pass, all the members of a biosphere evolve together, adapting to their terrain in a complex communal response, a creative self-designing ability. This process, no matter how much we intervene in it, is essentially out of control. Genes mutate, creatures evolve: a new biosphere emerges, and with it a new noosphere[2]. And eventually the designers' minds, along with everything else, have been forever changed.
This is the process of aeroformation."[3]

Over the two century long process of colonization political conflicts between environmentalists (the Red) and industrialist (the Green, bent on reshaping Mars into a second Earth) emerge as a direct result of the terra-forming of our neighboring planet. The foremost aspect of extrapolation is the change of Mars environment itself, well founded in geology, biology and environmental studies. Later, technical innovation based on visions of today are included, the most prominent being the space elevator, a cable linking the ground to a satellite in geosynchronous orbit.[4] The first elevator becomes a political weapon as it is destroyed by the Reds, and the cable drops down on the surface of Mars, wrapping around the planet along the equator. As the planet transforms, so does the identity of its colonizers. The first generation of settlers becomes divided and takes active part in the establishment of the Red and Green fractions. In time, ideologies become more important than technologies and an intricate web of incidents, on Mars as well as on Earth, are depicted through the eyes of different individuals.

Ambiguous Utopias[5]

"Reports. It filed reports. It had long since stopped trying to make them different or original.
The ship was bored. It was also aware of a continuing undercurrent of fear; a real emotion that it was by turns annoyed at, ashamed of and indifferent to, according to its mood.
It waited. It watched. Beyond it, around it, most of its small fleet of modules and satellites, a few of its most space-capable drones and a variety of specialist devices it had constructed specifically for the purpose also floated, watching and waiting. Inside the vessel its human crew discussed the situation, monitored the data coming in from the ship's own sensors and those coming in from the small cloud of dispersed machines. The ship passed some of the time by making up elaborate games for the humans to play. Meanwhile it kept up its observation of the Excession and scanned the space around, waiting for the first of the other ships to arrive."[6]

The most advanced AIs in the Culture are referred to as Minds, and they share the same rights of citizenship as any other sentient being. They are designed (by other Minds) with a craving for life, experience and understand, and are driven by curiosity. Culture starships are sentient themselves, with Minds relating to the fabric of the ship as the brain to a human body; the largest vessels are measured in kilometers and can carry millions of people as well as other spacecraft. AIs and Minds are critical to the series in that they are regarded as part of humanity as a species, and share the goals of the Culture as a civilization; balancing the desire of freedom of choice and contributing to society in general.

Historical Forecasting[7]

"Finally, Seldon stopped. "This is Trantor three centuries from now. How do you interpret that? Eh?" He put his head to one side and waited.
Gaal said, unbelievingly, "Total destruction! But – but that is impossible. Trantor has never been — "
Seldon was filled with the intense excitement of a man whose body only had grown old, "Come, come. You saw how the result was arrived at. Put it into words. Forget the symbolism for a moment."
Gaal said, "As Trantor becomes more specialized, it becomes more vulnerable, less able to defend itself. Further, as it becomes more and more the administrative center of Empire, it becomes a greater prize. As the Imperial succession becomes more and more uncertain, and the feuds among the great families more rampant, social responsibility disappears."
"Enough. And what of the numerical probability of total destruction within three centuries?"
"I couldn't tell."
"Surely you can perform a field-differentiation?"
Gaal felt himself under pressure. He was not offered the calculator pad. It was held a foot from his eyes. He calculated furiously and felt his forehead grow slick with sweat.
He said, "About 85%?"
"Not bad," said Seldon, thrusting out a lower lip, "but not good.

The actual figure is 92.5%."
Gaal said, "And so you are called Raven Seldon? I have seen none of this in the journals."" [8]

As Seldon also sees an alternative in which this period could be reduced to a thousand years, action is taken through the development of the Encyclopedia Galactica, a compendium of all human knowledge created by Seldon and a group of the most intelligent minds of the Empire. The storyline evolves over one millennium and 15 novels with additional short stories, with two additional societies (the Foundation and the Second Foundation) that are founded to maintain the advanced civilization but soon are regarded as threats. The series is generally considered to focus on the way a civilization may progress in a mode of self analysis, and using its history as precedent. With the concept of Psychohistory, another focus lies in the predictions in Seldon's plan, which is regarded as an inevitable mechanism of society. It is however based on group trends, and the storyline introduced a number of extraordinary individuals that could not have been predicted.

Dimensional Complexity[9]

""Huh? Wha' d'ju say?" Teal stumbled slightly in his flow of words, did a slight double take, and recovered himself. "Commissions. Correct. And why? Because I don't think of a house as an upholstered cave; I think of it as a machine for living, a vital process, a live dynamic thing, changing with the mood of the dweller—not a dead, static, oversized coffin. Why should we be held down by the frozen concepts of our ancestors? Any fool with a little smattering of descriptive geometry can design a house in the ordinary way. Is the static geometry of Euclid the only mathematics? Are we to completely disregard the Picard-Vessiot theory? How about modular system?—to say nothing of the rich suggestions of stereochemistry. Isn't there a place in architecture for transformation, for homomorphology, for actional structures?"
"Blessed if I know," answered Bailey. "You might must as well be talking about the fourth dimension for all it means to me."
"And why not? Why should we limit ourselves to the—Say!" He interrupted himself and stared into distances. "Homer, I think you've really got something. After all, why not? Think of the infinite richness of articulation and relationship in four dimensions. What a house, what a house—" He stood quite still, his pale bulging eyes blinking thoughtfully.
Bailey reached up and shook his arm. "Snap out of it. What the hell are you talking about, four dimensions? Time is the fourth dimension; you can't drive nails into that."
Teal shrugged him off. "Sure. Sure. Time is a fourth dimension, but I'm thinking about a fourth spatial dimension, like length, breadth, and thickness. For economy of materials and convenience of arrangement you couldn't beat it. To say nothing of the saving of ground space—you could put an eight-room house on the land now occupied by a one-room house. Like a tesseract—"" [10]

Unfolding this four-dimensional geometry into its three-dimensional equivalent, he designs a house with a minimum base with services, utilities and garage (to minimize the footprint), a six-room 1st floor would provide most other facilities arranged around a central space, and the top floor a single study with views in all directions.

He designs and constructs the house expediently, and soon his friend is coming to review the result with his wife. As they approach the building, all but the ground floor seems to have vanished. As they enter however, all eight rooms are still in place. During the night, an earthquake has turned the unfolded tesseract into a real tesseract, suggesting that Teal's design in all aspects except topologically was in fact a four-dimensional structure, and it just needed a little push to fall in place.

Spatial Anomalies[11]

"In one continuous shot, Navidson, whom we never actually see, momentarily focuses on a doorway on the north wall of his living room before climbing outside of the house through a window to the east of that door, where he trips slightly in the flower bed, redirects the camera from the ground to the exterior white clapboard, then moves right, crawling back inside the house through a second window, this time to the west of that door, where we hear him grunt slightly as he knocks his head on the sill, eliciting light laughter from those in the room, presumably Karen, his brother Tom, and his friend Billy Reston - though like Navidson, they too never appear on camera- before finally returning us to the starting point, thus completely circling the doorway and so proving, beyond a shadow of a doubt, that insulation or siding is the only possible thing this doorway could lead to, which is when all laughter stops, as Navidson's hand appears in frame and pulls open the door, revealing a narrow black hallway at least ten feet long, prompting Navidson to re-investigate, once again leading us on another circumambulation of this strange passageway, climbing in and out of the windows, pointing the camera to where the hallway should extend but finding nothing more than his own

1 Robinson, Kim Stanley, *Red Mars*, Bantam, 1992; *Green Mars*, Bantam, 1993; *Blue Mars*, Bantam, 1996
2 Noosphere is the idea of a third succession of the development of the Earth, following the geosphere (inanimate matter), the biosphere (biological life), that relates to when humankind creates resources through the transmutation of elements (such as through nuclear processes). The term was defined by Vladimir Vernadsky and Teilhard de Chardin. http://en.wikipedia.org/wiki/Noosphere (11/1 2012)
3 As Mars atmosphere slowly becomes breathable through Robinson´s concept of 'aeroformation,' the Mars colonists realize that the creation of a new world does not depend on technology alone.
Robinson, Kim Stanley, *Green Mars*, Bantam, 1993, p.13
4 This concept was first introduced by Russian scientist Konstantin Tsiolkovsky in 1895, but has later been further developed by other writers of SF such as Arthur C. Clarke (who also lends his name to the elevator space station in *Red Mars*) and lately a number of space agencies are considering it more closely.
5 The Culture series currently encompasses eight books and three short stories, the first being *Consider Phlebas* (1987) and the most recent being *Surface Detail* (2010). The Culture as a concept has also generated great interest among its readers, as reflected in the extensive Culture overview on Wikipedia. http://en.wikipedia.org/wiki/The_Culture (5/1 2012)
6 In *Excession*, the Minds and the human population of the Culture, Iain M. Banks galaxy spanning civilization, responds to the appearance of an artifact older than the universe itself, identified as an Outside Context Problem, something a society cannot foresee often resulting in catastrophic changes.
Banks, Iain M., *Excession*, Orbit, 1996, p.272
7 Asimov, Isaac, *Foundation*, Gnome press, 1951; *Foundation and Empire*, Gnome press, 1952 and *Second Foundation*, Gnome press, 1953
8 Mathematician Hari Seldon calculates the likelihood of the destruction of the planet Trantor, through Asimov´s invented science of Psychohistory.
Asimov, Isaac, *Foundation*, Gnome press, 1951, reprint, Panther Books, 1967, p.18
9 Heinlein, Robert A., '... And He Built a Crooked House,' first published in: *Astounding Science Fiction*, February 1941. Reprinted in Heinlein, Robert A., *The Fantasies of Robert A. Heinlein*, Tor Books, 1999
10 Ibid. p. 69
11 Danielewski, Mark Z., *House of Leaves*, Pantheon Books, 2000

backyard-no ten foot protuberance, just rose bushes, a muddy dart gun, and the translucent summer air - in essence an exercise in disbelief which despite his best intentions still takes Navidson back inside to that impossible hallway, until as the camera begins to move closer, threatening this time to actually enter it, Karen snaps, "Don't you dare go in there again, Navy," to which Tom adds, "Yeah, not such a hot idea," thus arresting Navidson at the threshold, though he still puts his hand inside, finally retracting and inspecting it, as if by seeing alone there might be something more to feel, Reston wanting to know if in fact his friend does sense something different, and Navidson providing the matter-of-fact answer which also serves as the conclusion, however abrupt, to this bizarre short: "It's freezing in there." " [12]

While trying to locate the best spot for their sofa, they realize that the dimensions of their house are flawed; it is larger on the inside than the outside. Through an escalating series of events; corridors that stretch far outside the outer boundary of the building appear, spaces shifts dimensions before their eyes, and a gigantic staircase leads the family (as explorers) deep into the earth. With careful analysis they calculate the depth of the stair to surpass the diameter of the planet, and carbon samples from the walls indicate materials older than the solar system.

Perceptual Constructions [13]

"When I was fourteen I saw Breach for the first time. The cause was the most common of all such – a traffic accident. A boxy little Ul Qoman van – this was more than thirty years ago, the vehicles on Ul Qoma's roads were much less impressive than they are now – had skidded. It had been travelling a crosshatched road, and a good third of the cars in that area were Besz.
Had the van righted, the Besz driver would have responded traditionally to such an intrusive foreign obstacle, one of the inevitable difficulties of living in crosshatched cities. When an Ul Qoman stumbles into a Besz, each in their own city; if an Ul Qoman's dog runs up and sniffs a Besz passerby; a window broken in Ul Qoma that leaves glass in the path of Besz pedestrians – in all cases the Besz (or Ul Qomans, in the converse circumstances) avoid the foreign difficulty as best they can without acknowledging it. Touch if they must, though not is better. Such polite stoic unsensing is the form for dealing with protubs – that is the Besz for those protuberances from the other city. There is an Illitan term too, but I do not know it. (Only rubbish is an exception, when it is old enough. Lying across crosshatched pavement or gusted into an alter area from where it was dropped, it starts as protrub, but after a long enough time for it to fade and the Illitan or Besz script to be obscured by filth and bleached by light, and when it coagulates with other rubbish, including rubbish from the other city, it's just rubbish, and it drifts across borders, like fog, rain and smoke.) The van driver I saw did not recover. He ground diagonally across the tarmac – I do not know what the street is in Ul Qoma, it was KünigStrasz in Beszel – and thudded into the wall of a Besz boutique and the pedestrian window-shopping there. The Besz man died, the Ul Qoman driever was badly hurt. People in both cities were screaming." [14]

Apparently ordinary events become extremely complex, as the inhabitants develop a capacity of "un-seeing" things that belongs to their sister city. The different areas of the twin cities are either total (an area that completely belongs to the city occupied by the observer), alter (areas that belong completely to the other city in regards to the observer, and therefore must be avoided and ignored) and crosshatched (common areas in which denizens of both city meets, but do not interact). There is also the Copula Hall, one of very few buildings that exists in both cities under the same name, and provides the only legal means to pass from one city to the other. The cities are physically very similar, but have slight variations in their architecture, fashion and artifacts. Any breaches of the formal codes of the twin cities are handled by Breach, a special organization that oversees and punishes trespassers. The narrative revolves around a crime investigation, as the assigned Inspector Tyador Borlú from the Extreme Crime Squad realizes that a murdered woman belongs to the neighboring city of Ul Qoma. The setting of the twin cities is explored through an escalating series of events, in which the conceptual framework becomes clearer and clearer, and in fact resides solely in the social patterns of the inhabitants. As the investigation shows that the victim was part of a group exploring the possibility of a third city, Orciny, Inspector Borlú finally have to consider making an act of Breach himself, and eventually becomes a member of the Breach organization allowing him to live in the two cities simultaneously.

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12 The recollection of the Navidson Record films by the fictional Zampano. Danielewski, Mark Z., *House of Leaves*, Pantheon Books, 2000 (2-color version) p.4
13 Mieville, China, *The City & the City*, Del Rey Books, 2009
14 Ibid., p.65

Design Project Strategies and Credits

This section includes outlines of digital design strategies at an operational level based on the formulated framework and the design projects enquiries of the previous sections, applied to the design projects of the thesis. These strategies are discussed in the design projects enquiry in the Strategic Implementations chapter, and relate to the design narratives presented with each project in the Projects book [Projects II: p.94]. Here, they are defined based on the previous arguments, and presented in a short and concise way. The 'design narrative' level of the operational design strategies are presented as part of the project documentation in the Projects II section of the thesis, referenced for each project below. The two projects included from the previous licentiate thesis are presented in a more extensive way in that thesis. Each project description below is concluded with project credits.

PARCEL

[Projects I: p.10]

Operational Digital Design Strategies

Types of engagement
Responsive performance; programmed behavior of light and sound.
Material performance; structure and form.
Modularization; componental and cellular approach in physical form, recombinatorial capacity and programmed intelligence.
Simulation; expected dynamic communication between cells.
Fabrication; an exploration of alternate fabrication methods.

Project aspects
Interior wall paneling system with responsive behavior through light and sound.

Design trope development or re-use
Folding principles and associated fabrication instructions, could be regarded as a digital design trope.

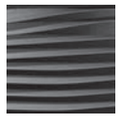
Design team configuration
Krets members shared the formal development, with the programmed responsive system being developed by one individual.

Design tactics
Prototypical development of material performance in regards to folding. Recombinatorial principles and final form explored through direct modeling. Further development through parametric modeling allowed alternate forms to be produced and combined.

Parametric patterns
The parametric model that combined a visual representation and a parallel fabrication template constituted a parametric pattern.

Project credits

Context: Developed within the Krets research group, www.krets.org
Designers: Pablo Miranda Carranza, Daniel Norell, Jonas Runberger
Main software employed: GenerativeComponents, Rhinoceros, Processing



SplineGraft

[Projects I: p.54]

Operational Digital Design Strategies

Types of engagement
Responsive performance; programmed behavior and actuators and material performance. Modularization; structural system and integrated electric network. Simulation; expected kinetic behavior employing actual code. Fabrication; the production of structural elements prepared for integrated electric network.

Project aspects
Wall paneling system with responsive behavior through kinetic mechanisms.

Design trope development or re-use
The geometrical and material principles of the moving spline entailed a design trope. The modular structural system with integrated electronic network entailed a second design trope. The parametric development of an alternate structural system suggested a potential third design trope.

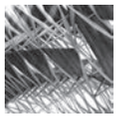
Design team configuration
The project was developed by two Krets members, with a division between design of physical form and development of behavioral systems.

Design tactics
Multiple simulations in parametric and generative software. Direct modeling of structural system, and subsequent parametric development of alternate structural system.

Parametric patterns
The parametric development of the alternate structural system could become, if further developed, a pattern that could be reusable.

Project credits

Context: Developed within the Krets research group, www.krets.org
Designers: Pablo Miranda Carranza, Jonas Runberger
Main software employed: GenerativeComponents, Rhinoceros, 3d-max, Processing



Flexible Space Frame

[Projects II: p.96]

Operational Digital Design Strategies

Types of engagement
Adaptive behavior; initial material studies and geometrical evaluations to explore basic adaptive principles.
Geometries and mechanisms; the analysis of geometrical deformation through scripted simulations and diagrammatic representations. Fabrication; composite material studies in physical as well as representational / diagrammatic form.
Architectural performance; performance evaluation in regards to formal variation and architectural effect.

Project aspects
Structure (with adaptive behavior), massing, envelope, spatial organization, urban organization

Design trope development or re-use
The development of a new design trope was required for the adaptive structural system.

Design team configuration
The overall process was driven by the student with continuous weekly support from the unit tutors. Initial material research was done as a team work. Additional support was given by AA technical tutors and specialists in parametric design, materials, digital fabrication and environmental design.

Design tactics
Analytical exploration of material performance in which series of composite physical models introduced the principles of the adaptive structure and structural integrity, and these behaviors were diagrammed in graphic representations.

Analytical evaluation of generative digital models where generated and transformed models through Rhino script simulated local and global geometrical transformations based on previous material studies, and the adaptive performance was documented in 2-dimensional diagrams.

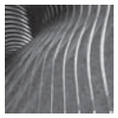
Physical mock-ups and references in which fabrication and assembly principles were explored through composite material models and informed speculative representations based on references of filament winding technologies.

Evaluation through design implementation, where architectural capacities of the adaptive structure were tested through advanced versions of the scripted digital models, and in directly modeled designs of bridge situation and terrace/ramp situation. Final design proposal was explored partly in digital and physical models and overall schematic models as well as renderings with material effects.

Parametric patterns
The simulation principle developed in rhino script could be re-used in several design stages, such as the four deployment studies and the two contextualized design proposals.

Project credits

Context: Architectural Association School of Architecture, Diploma Unit 16, 2008 – 2009
Designer: Kengo Skorick, student
Tutors: Jonas Lundberg, Jonas Runberger, Andrew Yau, Thomas Tong, with additional support from AA technical staff
Additional support. Jalal El-Ali, Daniel Norell, Nate Kolbe, Jeff Tourko, Brett Steele, Christos Passos, Pablo Miranda Carranza, Åsmund Gamlesæter, Daniel Fagerberg, Anne Save de Beaurecuil, Franklin Lee, Sam Jacoby, Johan Granberg, Giorgia Cannici, Gustav Fagerström
Main software employed: Rhinoceros and scripting



Slumbering Space

[Projects II: p.108]

Operational Digital Design Strategies

Types of engagement
Generative principles for form making; the spatial envelop loosely following different configurations of the human body.
Design rationalization; the breaking down of the overall envelope into strips to allow analysis and provide design identity.
Performance evaluation; an explicit evaluation of structural demands for each individual strip, and an implicit evaluation of strip widths for aperture control.

Project aspects
Massing / spatial study and envelope (with structural feedback and aperture definition)

Design trope development or re-use
The project is built up based on the initial generation with little re-use, the overall project can be seen as a re-usable design trope however.

Design team configuration
The project was developed individually with support from studio tutors in regards to design, parametric technique and structural evaluation.

Design tactics
Initial form generation through animation (facilitated in a parametric model) and subsequent associated envelope.
Aperture control of envelope components.
Local definition of entrance situation which entailed further parametric development.
Direct link between parametric model and structural analysis software for local structural requirements on envelope components.
Design evaluation through rendered models.

Parametric patterns
The overall project model was an associated system that with further development could be re-used either in a direct way (for similar design tropes) or adapted to alternate design principles (such as abandoning the strip configuration).

Project credits

Context: KTH School of Architecture, Studio 11 Architectures of Interdisciplinarity, 2010
Designer: Gregoire Stouck, student
Tutors: Lina Martinsson Achi, Hanif Kara, Jonas Runberger and Paul Scott
Additional support: Reuben Brambleby, Raimo Joss, Alexander Trimboli, Tim Anstey, Martijn Veltkamp and Marco Vanuchi
Main software employed: Rhinoceros and Grasshopper

Labyrinth Wall Pavilion

[Projects II: p.114]

Operational Digital Design Strategies

Types of engagement
Generative principle; for the development of specific architectural effects.
Structural principles; in analogy with architectural ambition.

Project aspects
Self-supported and articulated partition system for spaces without climatic control.

Design trope development or re-use
The overall project entails a digital design trope.

Design team configuration
The project was developed individually with support from studio tutors in regards to design, parametric technique and structural evaluation.

Design tactics
Generation of component-based partition system supported with partial structural evaluation.

Parametric patterns
Project specific parametric system could be regarded as a re-usable pattern.

Project credits

Context: KTH School of Architecture, Studio 11 Architectures of Interdisciplinarity, 2010
Designer: Elsa Wifstrand, student
Tutors: Lina Martinsson Achi, Hanif Kara, Jonas Runberger and Paul Scott
Additional support: Reuben Brambleby, Tim Anstey, Raimo Joss, Alexander Trimboli and Martijn Veltkamp
Main software employed: Rhinoceros and Grasshopper, Multiframe, Ecotect

Share / Mix / Invite

[Projects II: p.120]

Operational Digital Design Strategies

Types of engagement
Formal design system; reoccurring as a theme throughout the project.
Structural evaluation; initial development of geometrical principle.

Project aspects
Structural elements, massing principles and spatial organization.

Design trope development or re-use
Triangulated principle re-occurs throughout the project, but lacks consistency of design trope.

Design team configuration
The two design team members could divide the different aspects of the project development to allow for creative development as well as system development of parametric models and links to evaluation software. The work was supported by studio tutors in regards to design development and structural evaluation.

Design tactics
Formal design concept based on exploration of geodesic principles in the development of self-supported tube and elevated walkway. Subsequent deployment of similar geometrical principle used alternate structural logic.

Parametric patterns
The initial generation of the tubes could be regarded as a parametric pattern that was not re-used within the project.

Project credits

Context: KTH School of Architecture, Studio 11 Architectures of Interdisciplinarity, 2010
Design team: Elsa Wifstrand, Romain Alarcon, students
Tutors: Lina Martinsson Achi, Hanif Kara, Jonas Runberger and Paul Scott
Additional support: Reuben Brambleby, Tim Anstey, Raimo Joss, Alexander Trimboli and Martijn Veltkamp
Main software employed: Rhinoceros and Grasshopper, Multiframe, Ecotect

Adjust[ed] Folding

[Projects II: p.126]

Operational Digital Design Strategies

Types of engagement
Formal design system with integral structural support; the complete project was developed using variants of the same module. Daylight feedback to design model; two modes of direct feedback to inform design decisions. Fabrication; principles for module. Architectural and programmatic performance;
assembled system.

Project aspects
Structural elements, massing of assembled elements, spatial organization.

Design trope development or re-use
The formal elements of the project constitute a design trope re-used for all parts of the project.

Design team configuration
The two design team members could divide the different aspects of the project development to allow for creative development as well as system development of parametric models and links to evaluation software. The work was supported by studio tutors in regards to design development and structural evaluation.

Design tactics
Formal design principles; the first intuitive design principle of crumbled paper was refined into a folded structure that could address programmatic, organizational, massing, structural and environmental concerns in a rational way.
Analytical exploration of environmental effects; based on the folded design principles, two main approaches to feedback from daylight analysis informed design decisions.

Parametric patterns
The parametric principles of adjusting points as a basis for generated triangulated geometry was applicable in the design model with direct feedback, which in turn allowed the use of evolutionary solvers for form finding.

Project credits

Context: KTH School of Architecture, Studio 11 Architectures of Interdisciplinarity, 2010
Design team: Gregoire Stouck, Ecehan Esra Top, students
Tutors: Lina Martinsson Achi, Hanif Kara, Jonas Runberger and Paul Scott
Additional support: Reuben Brambleby, Tim Anstey, Raimo Joss, Alexander Trimboli and Martijn Veltkamp
Main software employed: Rhinoceros and Grasshopper, Multiframe, Ecotect

Amongst the Machines

[Projects II: p.132]

Operational Digital Design Strategies

Types of engagement
Overall massing principle; in order to identify beneficial situations for parametric development. Generative models; based on triangulation for space frames, envelope and ground articulation.

Project aspects
Structural principles with spatial concerns, cladding and ground articulation.

Design trope development or re-use
The project is based on different modes of triangulation, which while being reused in different aspects of the project cannot be regarded as a new design trope due to its generic nature.

Design team configuration
Individually developed project with support from the studio tutors in regards to conceptual framework, design issues, parametric development and structural principles.

Design tactics
Generative model was used to explore variants of triangulated space frame with partial cladding, in which the structural resolution was determined through implicit evaluation in conversation with structural engineer. Generated models were used as prototypes for the overall assembly, and cladding set the formal conditions for the associated public program, suspended in the space frame structure.
Triangulation principle for façade of the boiler house.
Generative model was used to define the base of the building cluster; a triangulated landscape that relates to the surrounding terrain, relates to the triangulated building skin and integrates with the interior at the entrance to the facility.

Parametric patterns
The triangulation principle could be partially re-used for the cladding, space frame structure and landscape applications, but separate parametric models were developed.

Project credits

Context: KTH School of Architecture, Studio 11 Architectures of Interdisciplinarity, 2011
Designer: Kathryn Bell, student
Tutors: Lina Martinsson Achi, Hanif Kara, Jonas Runberger and Paul Scott
Additional support: Reuben Brambleby, Tim Anstey, Raimo Joss, Alexander Trimboli and Martijn Veltkamp
Main software employed: Rhinoceros and Grasshopper

Subversive Resilience

[Projects II: p.138]

Operational Digital Design Strategies

Types of engagement
Conceptual integration; programmatic, technological and spatial aspects. Daylight analysis; pre-study. Massing and structure. Environmental performance; daylight and heat.

Project aspects
Massing, envelope, structure and spatial organization.

Design trope development or re-use
The combination of a diagrid structure and catenary curves provides a design trope that is applied for most aspects of the formal generation of the envelope.

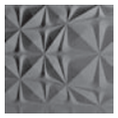
Design team configuration
Individually developed project with support from the studio tutors in regards to conceptual framework, design issues, parametric development and structural principles. Additional support through consultation from specialists in regards to programmatic issues (algae farming + CHP plant) as well as heat and energy.

Design tactics
Formal design principles with structural feedback; overall massing based on light studies and formal approach, the choice of combined diagrid and catenary curve structural principle for structural deflection analysis. Algae tube configuration; position of tubes for algae farming based on technical performance (in regards to sun exposure) as well as aesthetic preference (formal articulation, positioning and color variance). System diagram; understanding of the relations between technical systems through a diagrammatic mapping enabled the identification of different environmental aspects.

Parametric patterns
Parametric system for spatial organization abandoned in favor of a more intuitive organizational model, and the development of system for algae tube could be applied to different parts of the envelope.

Project credits

Context: KTH School of Architecture, Studio 11 Architectures of Interdisciplinarity, 2011
Designer: Anna Teglund, student
Tutors: Lina Martinsson Achi, Hanif Kara, Jonas Runberger, Sander Schuur and Paul Scott
Additional support: Reuben Brambleby, Tim Anstey, Raimo Joss, Fredrika Gullfot and Martijn Veltkamp
Main software employed: Rhinoceros and Grasshopper, Multiframe, Ecotect



Koggen Ornament

[Projects II: p.146]

Operational Digital Design Strategies

Types of engagement
Patterning; ornamental aspects of precast concrete façade elements (development was facilitated in isolation of general project development).

Project aspects
Surface articulation.

Design trope development or re-use
The parametric system development is generic, but the particular formal design principle can be regarded as a design trope.

Design team configuration
The conceptual development was facilitated by the author on the basis of a number of formal precedence, as well as preliminary requirements from the concrete element producer. The formal principle was approved with the overall project architect before final parametric development was completed.

Design tactics
Local variation of global pattern based on control surfaces; allowing a non specialist to alter patterns by manipulating the control surfaces through direct modeling.

Parametric patterns
The grid based system for the control of variation across the surface could provide a large number of local and global parameter control parameters, through the affiliated control surfaces. This system was used for the configuration of the ornament pattern, the depth of the ornament and the amount of curvature applied to the local geometry. It could easily be adapted to other situations.

Project credits
Context: Dsearch, White Arkitekter AB, 2010
Designer: Jonas Runberger
Design team: James Reader, Jonas Runberger
Main software employed: Rhinoceros and Grasshopper

Reframe

[Projects II: p.152]

Operational Digital Design Strategies

Types of engagement
Generic, self-supported, partition system; design system with linked fabrication instructions.

Project aspects
Generic parametric system; partition elements with light and see-through control, and inherent structural integrity. Applied system; reconfigurable staircase that also introduces the organization of different vertical routes in a building.

Design trope development or re-use
The system includes a new digital design trope consisting of a triangulated deep partition system, with a diagonal, stepped linkage between individual elements.

Design team configuration
The project was developed in parallel to an architectural competition, using a schematic design as the basis for an applied version including partition and staircase. The parametric system allowed reconfiguration through direct modeling as well as parameter change, which directly influenced the form of the two framework surfaces.

Design tactics
Global control of partition and framework surfaces through direct modeling.

Parametric patterns
The specific configuration of triangulated components could be reapplied to other situations, provided that two framework surfaces can be used to control components depth.

Project credits
Context: Dsearch, White Arkitekter AB, 2011
Designer: Jonas Runberger
Design team: Anton Kolbe, Sander Schuur (designers of the Serlachius Art Museum proposal)
Main software employed: Rhinoceros and Grasshopper

Quality Globe Hotel

[Projects II: p.158]

Operational Digital Design Strategies

Types of engagement
Project specific design system; parametric formal design concept for interior envelope for conference space.

Project aspects
Interior wall paneling system with visual and acoustic properties, developed in parallel to overall project process.

Design trope development or re-use
The design concept included a new design trope based on the combination of multiple lamella systems and triangulated elements for local articulation.

Design team configuration
The development was initiated through a design workshop with the author and two design team members participating. This session set the conceptual premises for the design, and inventoried technical and programmatic requirements. A basic parametric system was then developed by Dsearch, to be explored and refined by the design team members with support from Dsearch.

Design tactics
Formal design concept based on an overall parametric system of lamellas, and a secondary system of paneling. Model includes interface for exploration through direct modeling.

Parametric patterns
Both parts of the parametric system can be applied to any framework surface, and is therefore re-useable.

Project credits
Context: Dsearch, White Arkitekter AB, 2011
Designer: Jonas Runberger
Design team: Magnus Croon, Hanna Plato, Sander Schuur
Main software employed: Rhinoceros and Grasshopper

Drawing with Rules

[Cover]

Parametric patterns
The plate would follow the edges of the screens at their perimeter. The screens could not be folded in a way that would make them hide any part of themselves. The screens could not overlap.

Project credits
Context: The archives of Manfred Mendosa | www.flackmannen.se
Artist: Amelie Rydqvist
Techniques employed: Informal algorithm and hand made drawing.

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Robert Aish, London 2009
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Selected Events attended by author 2005–2012

Digital Design Strategies workshop
White Arkitekter AB, Stockholm 2012, facilitator

Final seminar doctoral thesis
external reviewer Marcelyn Gow (faculty SciARC), 2011

SmartGeometry conference 2011
Copenhagen, attendee

Digital Design Strategies workshop
White Arkitekter AB, Stockholm 2011, facilitator

Contemporary Practice. Beyond the Crisis
KTH School of Architecture, Stockholm 2010, moderator

Parametric Patterns,
Virginia Commonwealth University in Qatar, 2010,
workshop facilitator and lecturer

SmartGeometry conference 2010
Barcelona, attendee

Bioinspired Forum
Stockholm 2010, lecturer

Smart Geometry pre-workshop
KTH School of Industrial Economics and Management,
Stockholm 2009, facilitator and tutor

Architectural Machines Symposium
Architectural Association, London 2009,
invited speaker

ssark medialab seminar
special guest Hanif Kara, Stockholm 2009,
facilitator and moderator

ssark medialab seminar
special guest Lars Hesselgren, Stockholm 2009,
facilitator and moderator

ssark medialab seminar
special guest Robert Aish, Stockholm 2008,
facilitator and moderator

Licentiate thesis seminar
KTH School of Architecture, external reviewer Michael Speaks
(Dean University of Kentucky College of Design), Stockholm 2008

The Prototypical Shelter symposium
the Art University of Linz, 2008, panel member

Ben van Berkel and the Theatre of Immanence exhibition
Portikus gallery, Frankfurt 2007, exhibitor

Arkus, research for practitioners
Stockholm 2007, external reviewer

Creative Systems – Architecture in a new industrialized context
CINARK, The Royal Danish Academy of Fine Arts, School of Architecture,
Copenhagen 2007, attendee

Manufacturing Material Effects
Ball State University, Indianapolis 2007, attendee

SmartGeometry2007
workshop and conference, New York,
workshop participant and presenter

Metropolis Lab symposium
Copenhagen 2007, lecturer

MA Architecture & Digital Design Systems
London Metropolitan University, London 2006 – 20008,
external advisor and examiner

Space of Communication research group
the Städelschule, Frankfurt 2006 – 2007,
group member

Open House – Intelligent Living by Design exhibition
Vitra Design Stiftung, Essen 2006, exhibitor

AKAD
at Lunds Konsthall exhibition, Lund 2006, exhibitor

Visual Forum 2006
Center of Visualization, Gothenburg, presenter

Research Spaces conference
the Bartlett + the Slade, London, 2005,
presenting paper

Joining Forces conference
University of Art and Design, Helsinki 2005,
presenting paper

Onedotzero_stockholm exhibition
Moderna Museet, Stockholm 2005,
exhibitor

This doctoral thesis is situated within the digital design field of architecture, and is a continuation of the licentiate thesis Architectural Prototypes: Modes of Design Development and Architectural Practice, presented at the KTH School of Architecture in 2008. The doctoral thesis investigates the current status of the digital design field of architecture, and identifies a number of related discourses. Within this field, it identifies a period of formation, which in recent years has turned into a process of reformation. It contributes to this ongoing reformation by proposing two alternate areas of future practice and research within the field. A speculative approach is considered to be important for a continued mode of exploration within the field, and is suggested as away to bring new scope to the digital design field. A number of key terms from the field of science fiction studies have been investigated to support the construction of a speculative framework for further development. A strategic approach is regarded as crucial to the way new design potentials that have emerged within the digital design field to be implemented into general architectural practice, and to further inform the field itself. Key concepts have been imported from the field of strategic management in the formulation of a framework for digital design strategies. The notion of the prototype, as explored in the previous licentiate thesis, resurfaces as a prototypical approach, which could be equally employed in the speculative approach and the strategic approach.

The doctoral thesis is also situated within the field of research-by-design, in the way architectural design projects have been facilitated as contextualized experiments, selected, documented and aligned in regard to terminology, and analyzed through a series of design project enquiries.

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