Developing Digital Design Techniques.
Investigations on Creative Design Computing.

Birger Sevaldson

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This thesis is the result of long-term support and inspiration from many people.

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Abstract

Industrial designers, architects, graphical designers and others have slowly adapted to the new digital design tools. Most of this process of adaptation is about modifying traditional techniques to benefit from digital technology. But digital technology offers the possibility to rethink the design process even to a degree where our conception of visual creativity is questioned. The intention of this thesis is to investigate the preconditions for an expansion of the traditional design techniques, and to invent, explore, develop and systematise new techniques that are specially developed to draw advantage from design computing.

This thesis documents and develops a long-term exploration of a special type of design, the digital design that appeared during the nineties and that possibly started with the animation techniques introduced by Greg Lynn and the experimental use of diagrams introduced by Peter Eisenman.

This thesis, focuses on the early stages of the design process; the explorative phases before the constrains of realisation start to narrow down the options. It presents several approaches spanning from simple techniques such as "direct modelling" to complex design processes where the computer's potential as a creative design tool is exploited. The latter approach implies reaching beyond direct representation of the artefact and operates in stages of abstraction. This could imply an intuitive and tentative-heuristic process where the translation, transformation and interpretation of visual material are central. On the other hand, a process reaching beyond figurative representation of the artefact could implement a meticulous diagrammatic rendering of forces, agents and features that are not directly perceivable but nonetheless crucial for the design process, especially when dealing with complex contexts. These mappings of dynamic relations are treated as arenas for creative design innovation.

A central aspect of creative design computing is the generative potential in digital technology. This means that the computer is able to process data and

produce results from the input. The digits are generic and open to manipulation and processing. The computer introduces a certain loss of control where the end result of processes is not entirely predictable. It is predictable within a certain range; one process cannot produce the entirely different but within the range of the possible output of a process we cannot predict the output in detail. We can exploit this in our creative work. Computational modelling that takes advantage of the computer's generative power is used to produce a more-or-less abstract source material for design. While some designers work with generative processes in a less abstract way, this thesis explores a path where abstraction and alteration of the meaning and coding of data is central. There are many different approaches to creative work with the computer. These span from a perspective of artificial intelligence to parametric approaches where the result from a computational process is derived from the processing of certain input parameters. My perspective is the perspective of the design process were the designer remains the driving force despite extensive use of emergent design techniques based on digital technology. I regard this process to be based on two main driving forces:

- Human creativity of all kinds and in all variations: individual, social, cultural (participatory, adaptive, evolutionary).

- The design media: the design concepts, tools and technologies that are available (from pencil to computational photorealism, complex simulations and emergence).

From the particular perspective of the design process brought forward here, generative techniques are meant to produce an unanticipated output that would fertilise the design process. This process would still be monitored and controlled by the human designer. The thesis intends to develop, explore, map and describe some of these possible approaches.

The thesis propagates a view of the design process as non-conclusive open-ended and continuously under construction. Digital technology does not replace any existing design methodology, strategy, medium or technique. On the contrary, the new ideas stemming from the introduction of digital technology inspire us to develop richer and more varied approaches where the traditional ways of working are part of a whole.

This new and richer design process ambulates between rationality and intuition, between research and exploration, between the casual and the heuristic, the linear and the networked. When this manifold design process is strategized in a way that takes advantage of the synergies that surface in the process, I call this the Hybrid Process. The Hybrid Process is a richer multi-layered and heuristic design process that has much larger potential and

openings to develop it in different directions. The new digital design technologies demand and create a flexible and conceptual state where the design process alters between non-rational probing and rationalisation.

The thesis is divided into five parts including an introduction (part 1). The remaining parts represent four different perspectives shedding light on the field of digital design. Part 2 describes the current state of the art of digital design practice and design discourse and debate regarding digital tools and design media. Part 3 introduces a general discussion of the new design techniques. Part 4 presents empirical studies where my own practice and samples from my teaching and co-operations are conceptualised and analysed. In Part 5, the techniques are set into a broader context where intentions in the use of the techniques are discussed and finally treated as elements in a larger context of the hybrid process.

The thesis presents many results and conclusions, but if I should emphasise one main achievement, it is the clarification of the Hybrid Process offered as the primary conclusion of the thesis.

The thesis builds on a first-person insider perspective, which seeks to develop the possibilities and repertoires in design research further and to open a path for the practitioner researcher to deploy her own works as bases of an investigation.

The thesis argues that the value of this approach is based on the first-hand knowledge of design processes that is often not systematised and communicated but for which the only reliable source of knowledge is the practitioner.

1. Introduction

This project started in 1990.

My background is in furniture design and interior architecture. I was trained at the National College for Art and Design in Oslo (now part of the Oslo National College of Art and Design). This education is arts and craft based, a tradition that differs from the more academic architectural study programmes. My background provides an important starting point for the thesis, and influences my approach to the topic of digital design. Indeed, this background may well be the initial reason for my chosen main approach, the practice based research and research through practice.

After the Institute of Industrial Design[1] purchased the first ALIAS seat in Norway, I became its only user which led to a teaching position at the School were my main task was to develop digital design. This was in 1990. The powerful technology always gave me the feeling of unreleased potential. There must be so much more to this 3D-space in the magic box. Released from real-life constrains I soon realized that this was a machine for visual thinking. It was as much a machine for the development of ideas of space as for the simulation of space. I started to play around with the machine, creating abstract objects that potentially could have been realized but where realisation was not important. (Figure 1) The technology instantly defeated any agenda of the functional, of the logical and of the intended and concrete. Instead, what was at stake was the process, the vague imagination of a potential and the abstract unnamed shapes. I wanted to test my creativity with the machine. Spontaneous modelling was a new experience.

I exploited this potential in a series of designs and also began to teach. A small numerically controlled grinder also contributed to the experimental options of the computer lab.

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[1] The Institute of Industrial Design was then a part of the National College of Art and Design in Oslo. In 1995 the institute merged with the Oslo School of Architecture.
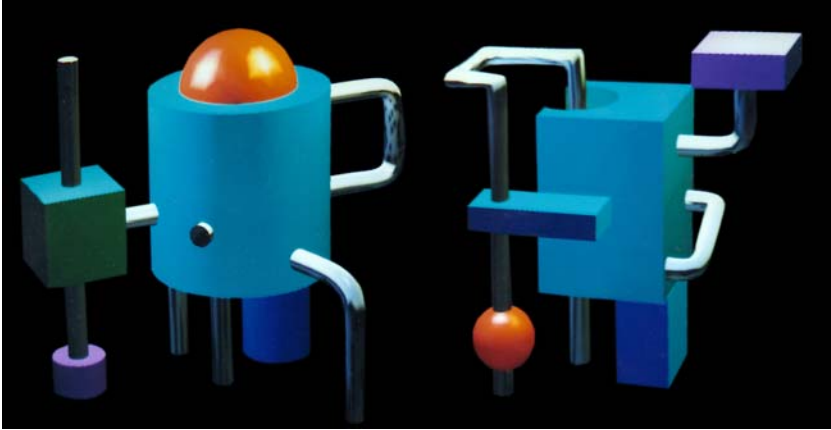
Figure 1 From the 'Tribe' series. My first attempts to take advantage from altering the design method with the help of a 3D system. The year was 1991, the system was ALIAS on a SGI Personal Iris workstation.

Meanwhile, I developed experience in computer-aided design through a long range of non-experimental designs (see Figure 2). These projects were of great importance because they gave me experience and background from 'real' projects, and involvement with companies, including the increasingly seamless file format exchange into production lines. I developed a computer literacy that was essential in the exploration of the experimental side. This is an aspect of my work that is not included in this thesis, which entirely focuses on experiments with digital technology. But it provides important background for this work.

The rudimentary traces of an experimental design practice developed further when I slowly became aware of the generative potential in the machine. The machine had the ability to surprise me. Maybe one of the first experiments were I was able to have some kind of control over the emergent process was the development of a series of objects with Boolean[2] operations (see Figure 3). This sample demonstrates a simple and fast way of generating complex spaces where the details of the resulting spaces is only partly under the designer's control.

The generative potential of the machine in this case means the ability to produce quite complex models from relatively simple input. Compared with other design media at hand, this was superior.

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[2] Typical Boolean operations in CAD systems are union, difference and intersection. These operations combine or subtract two or more solid objects.
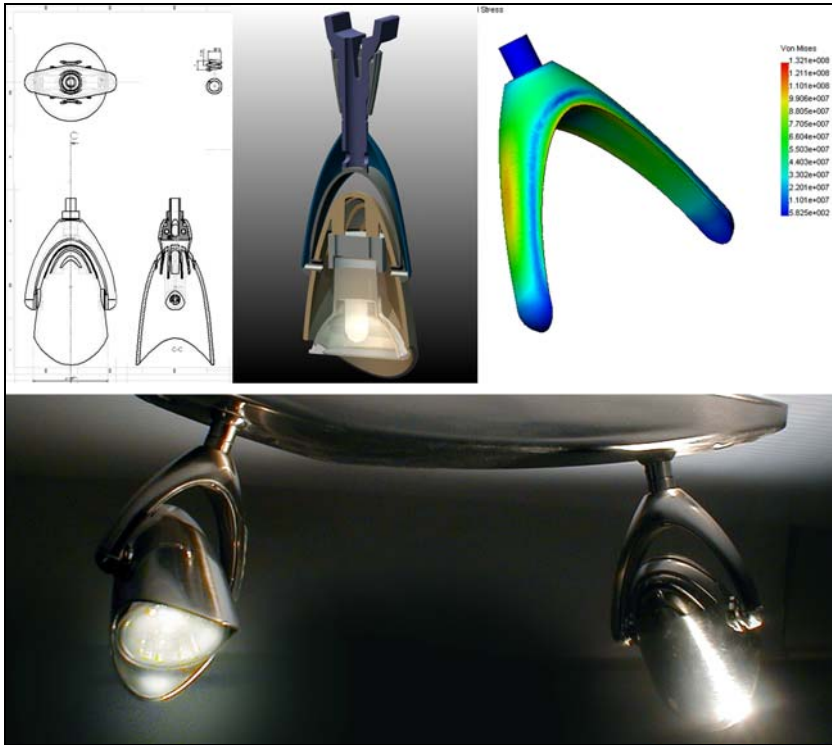
Figure 2 'Normal' design practice provides important background and preconditions for the development of my experimental design practice. A spotlight design for the Norwegian company SG Armaturen was developed through a process that included all steps of design and design engineering including a Finite Element Analysis (by my colleague Steinar Killi). This was important in making the right decisions for the construction. This is the only image of 'normal' design in this thesis. (Birger Sevaldson 2000)

The speed and accuracy transformed design activities that had previously only been possible in laborious and painstaking drawing and model making into a state of spontaneous design. This has wider implications for the design process: were the model in Figure 3 to be made in wood, the process would include the precise construction of drawings and accurate planning of the process. The realisation would be dependent on a high level of craft skill and laborious time at the work bench. This type of design would require considerable planning of the process and the output would be greatly influenced by material conditions.
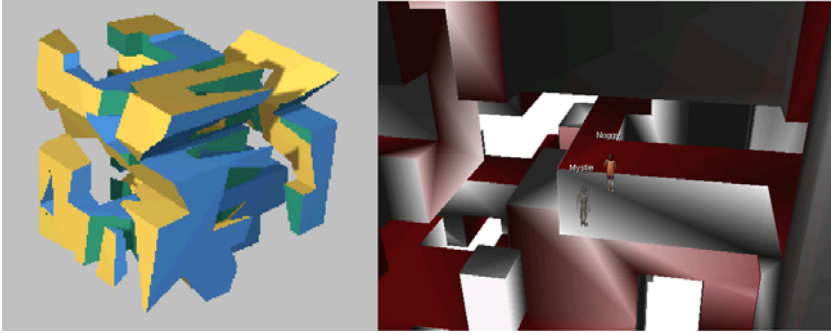
Figure 3 Playing with Boolean operations. Spontaneously drawn sections from three sides were used to generate objects. Maybe my first attempt with a simple form of emergent design. The result was not possible to foresee and it was always a pleasure to experience the complexity this simple operation produced. To the left: one of the many objects. (1994). To the right one of the objects used as an exploring space in the 3D-chat system Active Worlds (1997)

Features that are too thin and could easily break during manufacturing, and hollow areas that are not accessible with the tool would have to be avoided. The process is forced into a mode of planned composition. The similar process on the computer is quick and spontaneous and this alters the design process away from composition and control to experimentation, exploration and a generative mode. This playing with abstract spatial forms later led me to mind-games about a new form of diagrams. These diagrams would utilize a three-dimensional space and therefore be able to render more complex information than the traditional ones. The reading of these diagrams would be done by spatial navigation inside the diagram rather than looking at them from the outside.

During the next two or three years, I developed an experimental workshop for the students at the Institute of Industrial Design, the VORB workshop series[3]. I created these workshops as a laboratory to further investigate the assumed potential of the 'magic box'. My students were investigators, navigators and creators, working as pilots in the unexplored digital space.

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[3] One of the "laboratories" used for this research is the "VORB" workshop series at the Oslo School of Architecture. VORB stands *for "Virtuelle Objekter, Rom og Bevegelser"* (Virtual Objects, Spaces and Movements) VORB is a series of workshops at Oslo School of Architecture which started in 1997 initiated and organised by the author. The VORB project is thought of as both a teaching project and a research tool.

In 1996-97, I became a member of OCEAN.NET which later developed into OCEAN NORTH. OCEAN NORTH, together with teaching, has been the most important source of inspiration for my work. The teaching workshops and studios were always experimental, defining tasks that demanded a certain level of exploration from the students. They were used as laboratories to investigate new design techniques.

Since 1995 I have been working on this thesis. My doctoral design research has thus followed the development of this exploration in digital design during the course of a decade. Its function was a means of reflection and registration. During this time the fad of digital design in general and the fascination for the undulating surface and folding in architecture has already faded. I think this is a good time to round off the thesis. We are looking for new principles for the digital design process - not the already long established CAD concepts but rather issues that relate to creativity and to the explorative and generative dimensions of the design process. These might turn out to be generic principles that will survive the trends of design. I think this development and transformation of the design process is only in its beginning.

1.1. THE THEMES IN THIS THESES

1.1.1. Mind the mind gap

When looking at creative design computing today, we have to deal with certain dogmas that obscure the understanding of what these processes really are. The computer is regarded as a rational tool and what is seen on the screen is too often taken as simulations based on logic. If we want to understand what is going on and take advantage of design computing as a creative technique where parts of the design process are taken out of the designer's control and given to a machine, we need to accept that designers and artists are playing and experimenting with computers and that they often operate beyond pure rationality. Control and non-control is a central theme in this thesis. The question is not limited to the amount of control in certain phases of the process but might involve relinquishing control in one respect in order to gain greater control elsewhere. The loss of control in certain phases of the creative process might be beneficial and inspiring. This loss of control comes from the use of generative computing that produces a large amount of partly unanticipated output. The emphasis has shifted from the product to the process by which a large range of products can be evolved, all of which share characteristics. Hard control rests with the constraints of the processes.

A main motivation that drives the investigation of potentials in design computing is simply the urge to investigate the possibilities the technology offers. Later we worry about the why's and what's. If we want to contribute or understand these processes we need to accept an imaginary and intuitive mindset that is widespread amongst the people working this way. In fact an intuitive imagination is, I believe, a precondition to explore the potential in computers used in a creative way. Hence some of the work that is described here does not need explanation. It is the result of experimentation and "playing" with the technology, and did not have any more specific motivation. It is comparable to the work of many artists who refuse to rationalise or explain their work, because the work itself stands on its own. It is a phenomenon that needs no explanation or justification other than its existence. In parts of our work we worked more like artists than designers.

1.1.2. Prologue: The World Center for Human Concerns

To make it easier to understand what this thesis is about, I begin with an example.

In 2002, the Max Protetch Gallery[4] invited about fifty architects and designers from all over the world to create visions for the reconstruction of the World Trade Center. OCEAN NORTH's contribution was the World Center for Human Concerns. The purpose of the Max Protetch Gallery initiative was to create a vision of the future, to start the healing process by imagining what the architectural response to the events of the 11th of September could be. None of the visions were ever meant to be built.

World Center for Human Concerns :
Design Study Commissioned by Max Protetch Gallery, New York, USA for the exhibition
"A new World Trade Center" 2002
OCEAN NORTH: Michael Hensel, Birger Sevaldson, Achim Menges.
Project Members: Lip-Khoon Chiong - Morten Gregersen .
with: Urban Office, London - Jeff Turko
Digital Animations and Video Rendering:
Placebo Effects, Olso - Kim Baumann Larsen
Rapid Prototyping Institute for Industrial Design at the Oslo School of Architecture and Design - Steinar Killi - Are Nielsen

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[4] The Max Protetch Gallery is a prominent gallery that has specialized on art and architecture. See http://www.maxprotech.com/
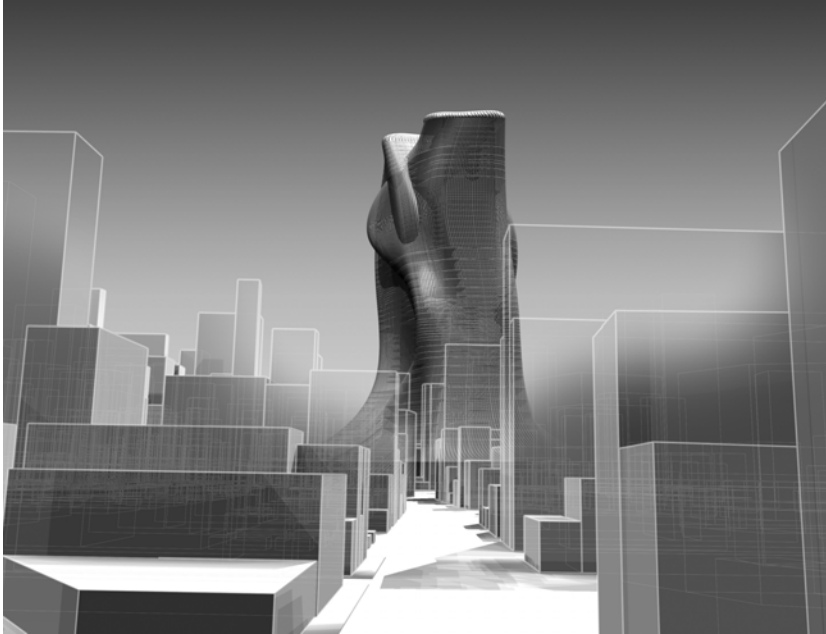
Figure 4 The suggestion for a World Center for Human Concerns would probably be the most voluminous and complex building ever built. In fact it is a vertical city with all thinkable types of systems facilities organizations and inhabitation forms.

Project description [5]

OCEAN NORTH's study for a World Center for Human Concerns for New York proposes a space for all peoples and cultures, whether existing or emergent. The 430 meter tall volume of our design proposal provokes a sensuous image of formation, continuity and multiplicity. It remains intelligible whether as one single object folding upon itself, or as two objects entwined in conflict or fusion. The object is both one and many at the same time, suggesting the multiplicity and connectedness of human existence. As a memorial to the drama of 11th September 2001 and a statement against all acts of violence, the volume of the World Center inscribes within itself the volume of Minoru Yamasaki's Twin Towers, which are visible as vague figures through the textured and folded skins of the new building. The World Center's spaces result from the draping and folding of the building skin around the volume of the twin towers. The draping articulates the building volume as a set of interstitial spaces that escape a singular spatial hierarchy and that create a heterogeneous relation between the built environment and

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[5] The project description is partly based on a rewriting of the World Centre project description by Michael Hensel to be found on the OCEAN NORTH website. See www.ocean-north.net

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its inhabitants. The design commences from the notion that dynamic relations between material object and human subject establish a potential space in which social, cultural and political experience can be located.

Every viewpoint grants a distinguished view of the object. Every route into and through the building provides a varied sequence of spatial experiences. The material make-up and striated articulation - similar to that of the previous Twin Towers - enables a modulated transparency of both the skin and the spaces within it. The scheme abandons the common high-rise organisation of central service and circulation-cores and uses instead the building skin as a space for circulation with 120 vertical circulation channels nested within it. The basket-like circulation system is developed into a structural principle, resulting in a system that will be less vulnerable to local disruption.

The new building will be inhabited by a manifold of programs and activities. It is regarded as a vertical city containing housing, business and entertainment quarters, cultural institutions and recreational areas. A vertical rain forest and areas which operate in different time zones are amongst the concepts for this type of vertical city.

Instead of an impossible horizontal expansion of Manhattan and the obvious difficulties with vertical growth, the scheme proposes a 'thickening' of the space of existing buildings by adding layers around them. With this approach arises a need for rethinking the question of daylight in deep plans and structures. By questioning an equal need for daylight, differentiated interior habitats can be articulated instead. Rainforests serve as organisational metaphor, where even in the lowest and darkest regions micro-ecologies flourish. This suggests a redefinition of what constitutes a 24-hour city. The darker core constitutes a 24-hour night zone, while the outer and peripheral areas enable a flexible negotiation of programs relative to less changing of the daylight.

The design illustrates the central issues and intentions in our experimental design practice and these or similar intentions are to be found in most of the design projects presented in this thesis. The development of the design illustrates some of the many digital design techniques that we try to implement in the development of inclusive design processes.

Phases of the World Center design

The design process might be phased in varying combinations and iterative sequences of, and alternations between the steps below described. The design process for the World Center was phased in the following way.

1) Development of the main concepts and examples given are concern with the wrapping of the original volumes, the connection of the draped surface to the horizontal city and the concept of using the draped and articulated surfaces as devices to create differentiated spaces throughout the depth of the structure.

2) Animation of wrapping skin around virtual volumes of twin towers; and the setting up of a generative dynamic diagram that deforms two wrapped skin surfaces.

3) Study of animation frames and selection of one frame for design development and remodeling of the surface geometry. Selection criteria were:
surface articulation with respect to the interstitial spaces produced by surface intersections; curvature continuity across the envelope, with the exception of the surface intersection areas; and Gaussian curvature analysis to strategize manufacturing approaches.

4) Further refinement of the geometry of the envelope through digital modeling and rapid prototyping studies.

5) Strategizing the skin articulation through curvature and striation and resultant modulation of the transparency of the envelope.

6) Development of combined structural and circulation strategy andplacement of structure and circulation channels in the building envelope.

7) Organisation of floor-slabs and development of a rationale for the deep plan occupation with respect to program and daylight;

8) Design finalisation.

The process was a partly remote collaboration with the group in London as the central project team.

The main concept for the generative animation was an 'animation machine' consisting of the following elements. A main space created a frame for the building volume. Inside this volume, two voids indicated the former twin towers. Within the frame, there were four mainly horizontal surfaces on which a number of cursors (spheres) were dropped.

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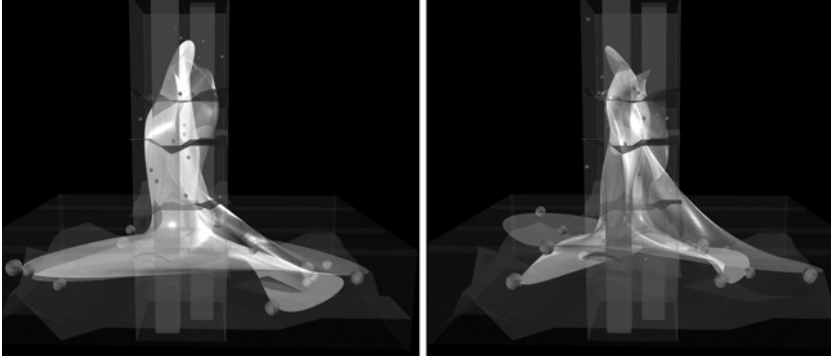
Figure 5 The set-up for the animation was a framed space with a series of free bouncing cursors that guided the surfaces. The bouncing of the cursors deformed the surfaces.

These surfaces had wrinkles and folds that caused the spheres to bounce off in different directions. The main frame prevented the spheres from escaping the volume. The spheres were linked to the control vertices of the two intertwined modelling surfaces and hence deformed the surfaces as they bounced off in different directions (Figure 5). This created an animation of 500 frames with a rich variety of forms (Figure 6)

The frames were investigated for their spatial and formal qualities and one frame was selected to serve as the starting point for the design of the World Center. Cross sectioning and other visualisation techniques helped to visualise the spatial richness and variations (Figure 7).

The chosen frame was taken through several steps of refinement. Surface modelling to develop the surface continuity and smoothness and the articulation of the intersections between the surfaces were indicators for the modelling.

The construction of the building was solved with a basket structure in the façade (Figure 8). This acted as both a structural construct that was considered to be both flexible and solid and as an organising device for the vertical transportation systems, while also contributing to the further articulation of the façade.
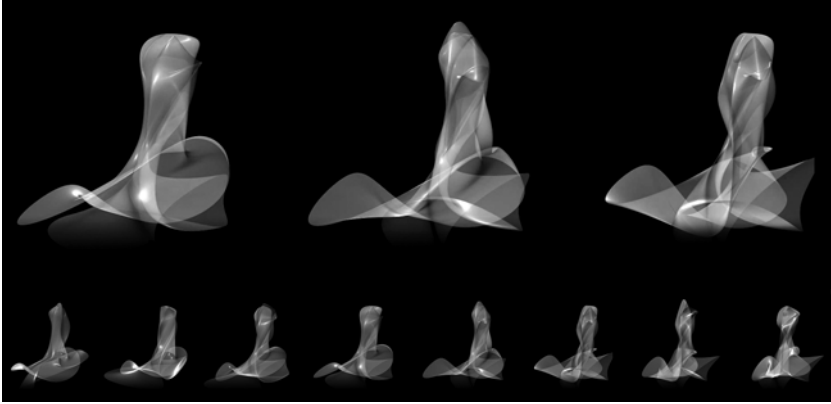
Figure 6 Top row shows three of the resulting 500 frames of the deformation animation
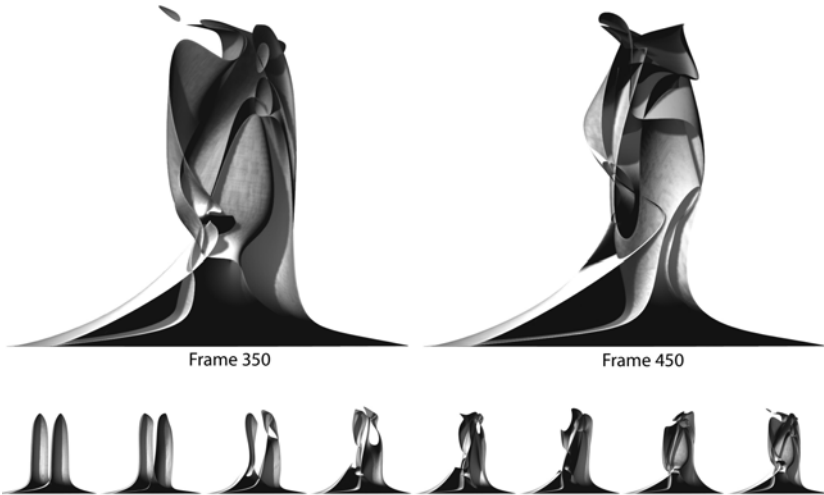
Frame 350   Frame 450

Figure 7 Cross section of frame 350 and frame 450. The cross sections revealed the richness and complexity of the nested spaces.
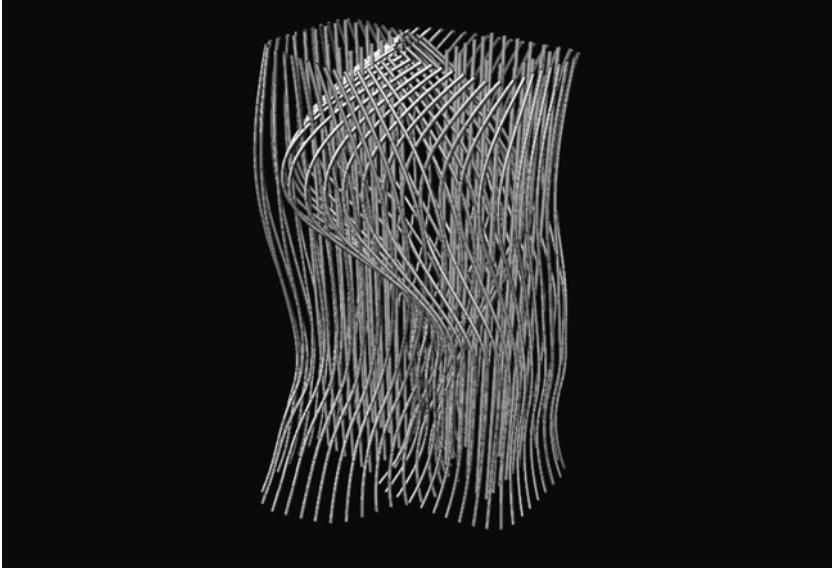
Figure 8 Diagram of the basket structure for the World Center. The outer surface both contains communication systems and provides the building with its structural strength.

Figure 9 Detail of the façade showing the suggested networked system of vertical transportation channels and the striation of the façade.
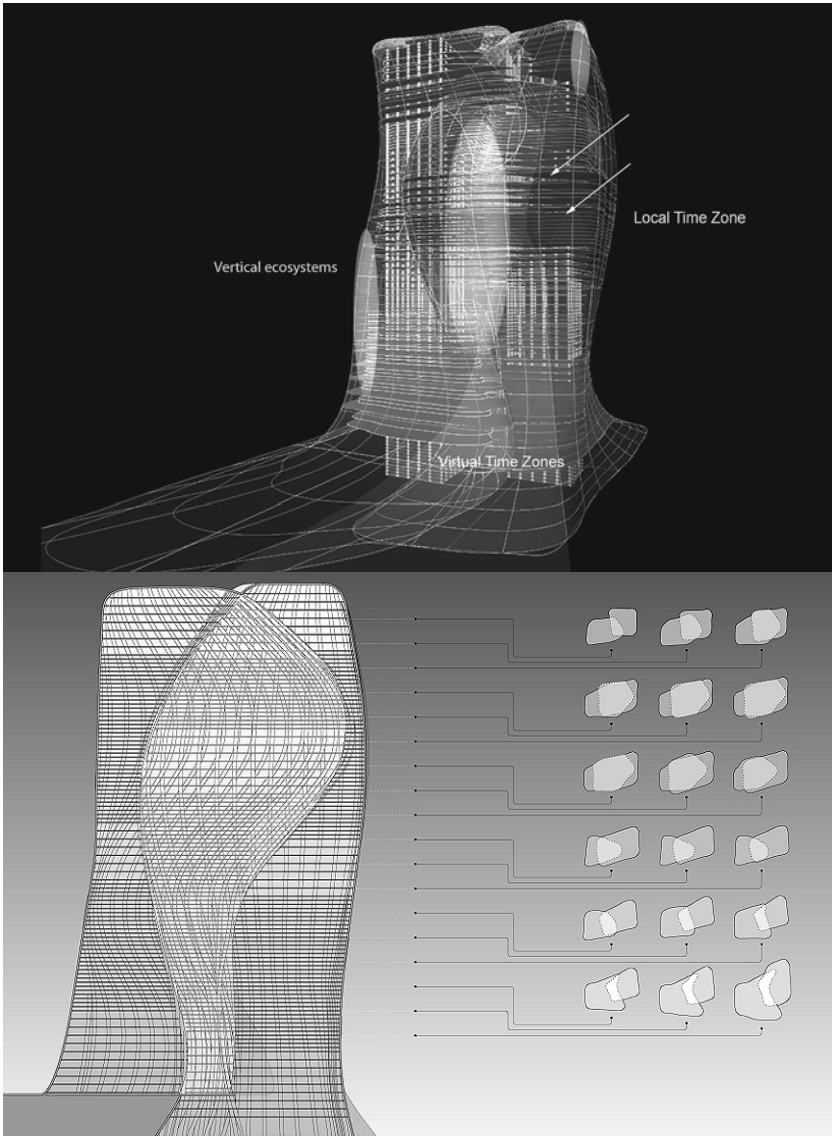
Figure 10 Top: Sketch showing a suggestion of possible structuring of the internal spaces which, running solely under artificial light could function in different time zones from the peripheral areas which are influenced by daylight. The image also shows the idea of vertical parks or "rain forests" (green areas) that would develop ecosystems over time. Bottom: Selection of floor plans showing the organization of the internal spaces.
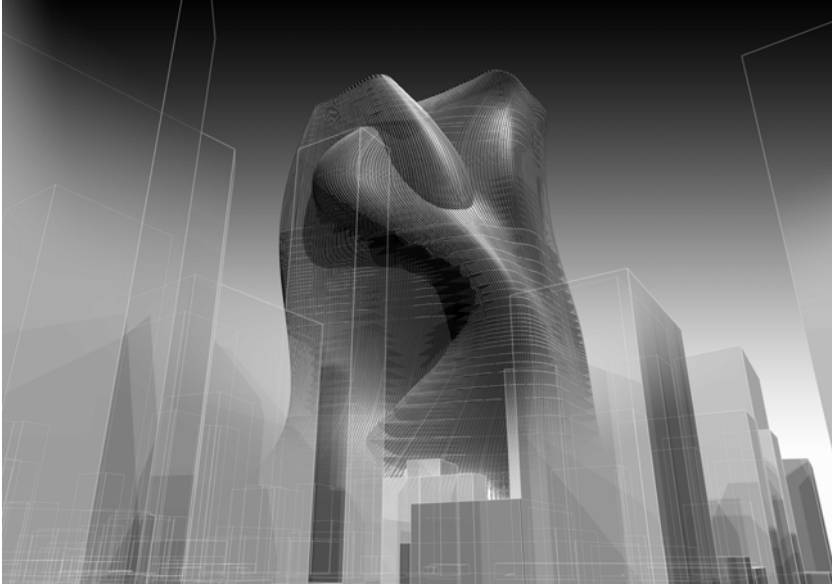
Figure 11 The final World Center for Human Concerns.

The façade was designed with a striation pattern allowing the regulation and differentiation of transparencies. The altering transparency of the façade would contribute to the differentiation of the internal activities and programs. These programs would include everything thinkable in a normal city plus a series of new features and facilities. These include housing, hotels, offices, cultural institutions, public areas, parks, cinemas, shopping malls, and the formation of real vertical neighbourhoods.

In addition to these programs that one would normally find in a city, that are mainly organised along a horizontal topography, radically new programs were suggested. These would run according to a different time scale than the local one. Independent of natural lightning, one could imagine the shifting of time scales. Certain parts of the inner areas could follow the time of other parts in the world, thus providing a unique environment for global connections (Figure 10).

The World Center project contains many of the elements that are discussed in the thesis. The construction of a "designing machine" that produces shapes for further design; the collaborative effort which in this case crossed geographical boundaries; the sequential work style that rejects the control of one singular designer, and the inclusive design process that suggests and negotiates many aspects into the project.

1.1.3. Creative computer use

In recent years the production of digital spaces has increased dramatically. In movies, videos, commercials, games, architecture, art and many other fields, virtual spaces are created and used for many purposes. The discourse following this "revolution" has only vaguely touched upon what seems to be one of the most important questions: the underlying technological constraints and possibilities of visual computing imply a shift in the way we work as designers. How does this shift influence the creative process? Prior to this question lies an assumption that design tools can have a crucial impact not only on the way we work but also on the way we think when we design. A new and very powerful technology has entered the design process. One should assume that this has a fundamental impact on the creative design process and on its results.

In the early stages of three-dimensional spatial planning (such as initial phases in architectural design or design of smaller artefacts), the development of new design techniques has so far only taken place to a rather limited degree, unlike the remarkable changes one can observe in graphic design. The reasons for this could be that we face severe difficulties when we try to use the computer in a creative way to design spatial constructs because 3D-applications lack some of the lightness and directness of 2D applications. The third dimension multiplies complexity in the software. Furthermore, spatial design and planning of physical environments and objects is intricate when it comes to the issue of representation (rendering), whereas these problems are absent in graphical design where "What You See is What You Get".

Another explanation could be that many designers are conservative when it comes to the development of new design strategies. While the adaptation of computing in graphic design seemingly went quite smoothly and triggered a creative boost, the implementation of creative computing into the early phases of three-dimensional design seems to be a more serious challenge to the familiar way of working. This incitement for change is challenging our myths of the creative process as an internal affair. As long as we believe that creativity is something that comes from deep inside of us we will tend to resist the potential of an external technology to influence this process.

The complexity of these explanations points to the fact that there is a lot of work to be done both in the development of software and of design methods. This thesis intends to contribute to the development and systematisation of new design methods and techniques to utilise the potential of the computer as a creative tool. Central in this endeavour stands the use of the computer as a generative design engine.
Despite the relatively slow progress in spatial design, in some circles the implementation of computers in design practices has triggered an interest in

the design process and in the invention and development of new design methods, strategies and techniques. This happens mostly in academic environments, amongst students and staff of some schools of architecture.[6] We can also find this development in some avant-garde practices.[7]

This has consequently led to a temporal decline of the importance of traditional design skills and to the appearance of a new generation of designers with no traditional education.[8] These designers base their work on an intuitive trial-and-error process. Also the sub-cultural aspect seems to be strong together with collection and recycling of graphical material. More recently, the traditional design skills appear to have had a renaissance where drawing skills are paralleled and combined with computer driven techniques and where this results in a new synergy.[9]

Computational modelling that draws on the computer's generative power is used to produce a more-or-less abstract underlay for design. There are many different arguments for such a way of working. They span from a perspective of Artificial Intelligence meant to replace human creativity, to parametric approaches where the result from a computational process is derived from the computing of certain input parameters. Our perspective is the perspective of the design process. I regard this process to be based on at least two main factors:

- Human creativity in all its variants: individual, social and cultural.
- The design media: the design tools and technologies available. (From pencil to computational photorealism, complex simulations and emergence)

From a perspective of design methodology, generative techniques are meant to produce an unanticipated output that would fertilise the design process. This process would still be monitored and controlled by the human designer.

The use of generative material raises questions about the creative process and the role of the designer:

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[6] We can mention The Architectural Association School of Architecture in London, The ETH in Zürich and several schools in the US.

[7] E.g. Ben van Berkel, DECOI, see the publications from the FEIDAD award for an overview of new and established practices. (Liu, 2002)

[8] An example of high quality, which also contains links to other operators within this sub culture of web design, is to be found at www.ziggen.com. This is the homepage of the Norwegian Siggurd Mannsåker who has the status of a guru in this milieu of very young enthusiasts, several of whom have become professionals.

[9] This trend is found at the Institute of Industrial Design where advanced CAD, CAE, CAID, DTP, image processing and digital video skills are combined with traditional drawing techniques.

- Can we still talk about a creative process when large and crucial parts of the output are generated by a machine?
- Can we still claim to be designers when our level of control is reduced?
- Can we be credited for accidents?

In art, the accident has played an important role for some time and the answer to the above questions seems to create little debate. The accident's role in the creative process may be traced back to expressionism where artists developed a more direct, emotional, spontaneous and seemingly less controlled technique. Edvard Munch left his unfinished paintings outdoors for longer periods to weather them, an effect that was not entirely under his control. An always returning example is the work of Jackson Pollock where his semi-controlled pouring of paint onto the canvas is interesting because of its instant negotiation of control and accident. There exists a small movement around the concept of Ars Accidentalis. The main source of information is from the Dutch Electronic Art Festival of 1997 to 1999 (Muller, 1999).

Creativity and the internalised elements of the creative process remain puzzling and unexplored phenomena. Many different explanations contribute to the understanding of creativity.[10] These explanations span from pragmatic, psychometric, cognitive, social-personality models to confluence models that try to embrace creativity as a multiple component phenomenon. Parallel to these models, which all stem from cognitive research, an experience-based understanding of creativity exists within the creative professions. This expertise is so far virtually unrecognised, partly because of lack of documentation.[11] The design-practitioner's perspective of creativity is based on first-hand experience rather than clinical research. This perspective might prove to be more productive for design research than models from cognitive science.

The designer as practitioner has unique first-hand experience that provides an understanding of how visual creative techniques work. From such a position, we can investigate our own creative processes regarding our intentions and the achieved results. We investigate the symptoms (products) of creative processes rather than the mysterious internal causes. I suggest this as a productive attitude for the design researcher in developing an understanding of creativity. This perspective focuses on the design process and the development of design creativity as a practice. It seems to be more efficient to develop the way we work as designers than to focus on the very

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[10] See "Handbook of Creativity" (Sternberg, 1999)

[11] There exists some studies conducted by psychologists and based on interviews of designers and other creative professions (Csikszentmihalyi, 1996) I have not found a similar valuable study by a design professional with the intention to clarify internal concepts and understanding of creativity in the design professions.

complicated issues dealt with by creativity researchers. I am looking here for a distinction between basic research on creativity and applied research in relation to a specific profession. By basic research, I mean the research done by cognitive science; applied research is in relation to specific professions, for example creativity development in business schools or the development of design methods.

Despite there being many diverse interpretations of what creative processes are, common to all explanations is the emergence of the unanticipated. Creation implies the arrival of something new, something that has not been imagined before in relation to the context of what has previously existed.

Computer technology has helped to simulate and calculate things that have been too complex for human imagination. The computer becomes a tool of investigation and exploration because of its incredible speed and storage capacity. Numerous discoveries have been dependent on computer technology, (e.g. the discovery of chaos mechanisms in the seventies). With the computer we can perform calculations that were impossible before. The results can be visualised by means of powerful graphical systems which expand the research into the production of visual evidence. Equipped with a graphic system, the computer becomes an engine for qualitative research where spatial formations, patterns and structures are explored. This implies an inductive mode of reasoning and knowledge production which is different from the number-crunching simulation-based research mentioned before. Though the core technology of the computer is digital, its graphic surface and interface turns it into an analogue machine able to store, manipulate and produce qualitative and visual material. This turns the computer into an "engine of the unanticipated".

Yet if we as designers were to leave everything entirely to simulations, genetic algorithms, artificial intelligence and expert systems we would see at least two negative consequences. The designer would be reduced to a less creative workhorse and the results would be unprocessed formalism with no cultural content or meaning, since culture in human interpretation has no meaning to machines.[12]
Fortunately this imagined automated design process is not current reality. We could rather argue that the creative moment has shifted from the creation of visual material (patterns) to the setting up of processes that generate pattern and to the analysis and evaluation of the pattern.

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[12] Greg Lynn says that .. *the failure of artificial intelligence suggest a need to develop a systematic human intuition about the connective medium rather than attempting to build criticality into the machine.* (Lynn, 1999)

To develop the potential in computer-aided design we need to:

• Visualise abstract structures: the setting up of the toolset and the production of patterns.
• Connect design thinking with visual computing: deriving the underlying laws, defining the ranges of pattern variations, refining the toolset.
• Take advantage of the computers generative power: running the process repeatedly introducing new variants.

The instrumental techniques suggested in this thesis are based on the implementation of the computer as a visual tool and the designer's interpretation, speculation, codification and manipulation of the computer-generated output. These techniques indicate a slightly altered but not alien role for the designer through the setting up of systems, the tuning of parameters, selection, interpretation, analysis and modification.

The strategies and techniques are not meant to necessarily contradict or replace any existing technique, technology or method. New technology makes some techniques outmoded while others will survive. The suggested techniques are an addition but only partly a replacement of traditional ways of working. I suggest that computer-aided creative techniques might partly replace the notion of internal creativity.

The techniques are targeted especially at the earlier stages of the process and would naturally be followed up by phases of traditional design work in refinement, development and detailing. But also here, computer technology has altered the process. The integrated CAD/CAE/CAM[13] packages challenge the established design and engineering phases. Easily accessible Finite Element Analysis[14] makes it possible to move engineering into early design phases to eliminate high risk constructions already at an early stage, and pattern generators can be informed by manufacturing constraints right from the start.

This thesis is based on the position that design processes are as much a result of practical activities as of cognitive processes (as well as social, emotional, education and historical/political aspects). These practical activities can be altered and have historically been altered independent of the cognitive understanding of the processes. New models of creativity within the tradition of cognitive research have reached positions, which lead to similar conclusions. (Confluence approaches to creativity) (Feldman, 1999)

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[13] Computer Aided Design, Computer Aided Engineering, Computer Aided Manufacturing.
[14] Computer aided method to calculate the solidity of construction.

This thesis is less concerned with design as a problem-solving activity than as a visual creative process. In this perspective design processes might solve problems or be problem-oriented, but what distinguishes them from other types of problem solvers like engineers or programmers is the emphasis and focus on form. The core of the design activity is "form giving". (Like the Scandinavian word "*formgivning*") This implies that form does not necessary appear as a solution to a problem but as one of uncountable possible appearances and as an additional value beyond the solving of targeted problems. (Thackara, 1988)

1.1.4. Design strategies and techniques

The term design strategies or design techniques will replace the term design methods or methodologies throughout this thesis. This is done to distinguish them from the global models of design methodology and the historical undertones these carry. The terms design strategies and design techniques are meant to represent a much lighter mode, not claiming global normative value, but being open to change and reconfiguration. In fact the term *strategy* implies that they are meant to be adapted to the conditions of each design task while design techniques are developed on a tactical level.

- Strategy: each design task and project demands its corresponding process.
- Tactics: the process changes and adapts in response to upcoming challenges.

To fully benefit from the potential of computer technology in the design process it is necessary to rethink the way we use technology in the design process. This research has to follow other paths than traditional design methodology, which has demonstrated its limitations so clearly (Gedenryd, 1998). First of all it has to break the paradigm of understanding these processes from the withdrawn position of the observer. Even the concepts of reflective practice have this limitation, since they attempt to make conscious the design processes that in periods are intuitive, tacit and not always explicit. Louis Pereira presents the following criticism of Protocol Analysis applied to design practice (Pereira, 2000) :

(1)   Protocol analysis is impractical for covering the complete design process,
(2)   It ignores the presence of cognitive processes not dependent on language and inference.
(3)   It has not been able to apply its findings to design practice.

To simultaneously keep a protocol while designing is disturbing in that it alters the process and in the end what we observe is no longer what we thought we were observing. Alternatively, we can verbalize and rationalize later (post-rationalisation).

Instead of explaining the creative design process from a cognitive perspective, we need, as design researchers, to focus on the production of processes. This means to alter, invent and design processes rather than to pursue the idea of generic, common and "standardised" processes. The design process has the nature of a heuristic spiral ambulating between practice and verbalisation, where the practical work and exploration appear both as a means of thinking and a production facility for empirical material.

The practical process can function as a 'theory engine' where pre and post rationalisation are major driving elements and where these rationalisation phases are well-documented, systematic and feed back into the process:

Practice >> interpretation >> theory >> interpretation >> practical implementation >> interpretation >> theory >>

Processes become what we make them become. They are not there as stable phenomena to be observed and explored by means of one or other technique. They are themselves emergent and adaptive, evolutionary, reflexive and a knowledge-building activity. Design research in this sense is about initiating change rather than observing and understanding what is there, or solving preset problems. (For more on initiating change, see Robinson, 1993 : 443)

For design work, which engages the use of new digital technology, we are challenged to invent new design techniques that are specially designed to engage the potential of computer technology. These techniques have to be articulated and explored in terms of their roles and constraints.

This thesis suggests that if we want to alter and develop design strategies we should look to the structural levels of these processes rather than the content level. This means that at certain stages of the process we work on a diagrammatic level, representing possible configurations of generic elements and forces. This is an initial level which avoids typology and semantics. A simple example is from my own experience as furniture designer facing the task of designing a dining chair. The noun "chair" immediately produces a conceptual image, the archetype of a chair with a seat, a back and four legs. The archetype becomes an ever returning obstacle when trying to be innovative and come up with new solutions. One strategy to bypass this deadlock is to rather work with terms like "seating" or "support" than the noun "chair" (suggested as a design strategy by my former teacher Professor Svein Gusrud). These terms focus more on processes and relations than on

objects. This means we depart from the static perspective of the object and start to look at sitting as complex and dynamic events. This subsequently leads to an even more liberating perspective when we start to look at the act of seating in structural terms as the relation between a number of entities, structures, forces and processes over time. Forces could be both physical (e.g. gravitation) and social (e.g. territory, separation, contact) or other categories. Forces and relations are rendered in diagrams and abstract or concrete models. Abstraction is applied as a design strategy also to involve visual thinking. The computer is well-suited to work in this way.

1.2. OVERVIEW

This investigation focuses on the concept of using digital tools and techniques in the design process. It focuses particularly on the early, imaginative, tentative, iterative and creative phases. It explores the potential in these techniques.

Experimental design:
The thesis concentrates on experimental design processes. The process is seen as an arena for an experimental approach to work as a designer. The thesis claims that these experimental design processes are intuitive and systematic, rigorous and spontaneous. The thesis is located in the crossover between design, art and architecture.

Early design phase:
The thesis develops, presents and suggests possible concepts for creative design techniques in digital design. It concentrates on initial phases of design, but in some cases I go further to illustrate how an initial design phase can continue into phases of realisation.

Practice-based research:
The thesis is about practice but inspired by recent developments in architectural theory and practice, arguing from and for practice-based research.
The practice spans from 1990 to 2004

Basic research:
The thesis is meant to be 'internal to the field,' as basic research for design practice, rather than 'applied' – it is not directed into 'the real world'.

First-person research:
The thesis is a single person investigation despite the fact that much of the material and many of the cases are produced in co-operation with colleagues or students. The thesis takes advantage of the insider perspective, and hands-on experience is essential.

The thesis is explorative and inventive:
The empirical base for the thesis is not 'stable': it is about *developing digital design strategies*, through active engagement as a designer involved in developing such strategies and through reflection on digital design as it continues to develop.

1.2.1. Main issues

The exploration in this thesis is focused on three-dimensional design such as product design and architecture. It focuses on design techniques in relation to creativity. The main issues that I discuss are degrees of control, abstraction, finding, visual thinking, negotiation, open-endedness, interdisciplinary cooperation, experimental design and the hybrid process.

Control and non-control
The idea that 'the more control the better' is questioned here. The digital design process creates a space for the unanticipated. The central aspect is about loosening control and developing strategies for the negotiation of control throughout the process.

Abstraction
The thesis claims that abstraction is better suited for the exploitation of digital creativity than types, metaphors and symbols. Diagrams are the tools of abstraction – they help to establish working definitions in design contexts and significance as you conceptualise 'the diagrammatic'. They work as generative tools in digital design techniques. Diagrams are tools to both describe and generate responses to the social and cultural forces in an urban context. Generative diagrams work as 'possibility triggers' in the design process.

Finding
The thesis sheds light on 'finding' as a creative strategy.[15] This is an external (inspired impressive) creativity rather than an internal (expressive) creativity.

Visual thinking
My use of the term visual thinking is entirely based on Rudolf Arnheim's description of the relation between perception and cognition. The most central source is his book from 1969 "Visual Thinking" (Arnheim, 1969). The main reason why I found it so useful is that it delivers a theory of abstraction and structural thinking that is necessary when we work with

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[15] 'Finding strategies' is a term used in different contexts like in the design of search engines for digital stored information or in the search for employment. I could not find any source where finding is directly linked to creativity. I find this a little strange and I must have overlooked some sources here.

emergent material. In a practical sense, visual thinking is apparent throughout the generative design process where the output from generative work is analysed and coded. Visual analyses of the found or generated visual material including recoding are central aspects that enable the exploitation of the generative potential in graphic computing. Visual computing has the potential to emphasise and develop the visual parts in a design process. These are tentative and intuitive design processes, form-giving and composition, play and game-based processes, diagramming and the mapping and development of complex processes.

I will return to the topic of visual thinking in depth later in this thesis.

Negotiation
To enable the computer to become a creative design tool we need to implement a less absolute and insistent design process. An important strategy for this is negotiation. Negotiating and responding to certain situations, rather than implementing control-driven and forced planning, opens the potential for creative fertilisation of the process by the generative material. Negotiation also involves the themes of flexibility and adaptability in design. Negotiated solutions are potentially more adaptable and flexible. This effect of negotiation can be used as a strategy to built adaptability into the solutions.

Open-endedness
The issues of control and negotiation lead to a view of design as being imperfect and changeable rather than aiming to achieve a complete and perfect composition. This enables a design solution to have a greater potential to adapt and adjust to future changes. It implements the notions of unfinishedness and open-endedness. These are important perspectives to engage the generative potential of the computer. Open-ended, complex, continuous processes can benefit from digital design approaches.

Interdisciplinary approach
Our approach draws on many disciplines spanning from art to object and building design: emergent design, object–design, architecture, urban design, electronic art installations.

Experimental design
The thesis discusses several experimental approaches where many of the designs are not realised and were never intended to be. These experiments, as well as the main perspective of the thesis, discuss the design process rather than being directed toward realisation. The term *experiment* is not used here in a scientific sense requiring an isolated setup in laboratory conditions. It is not based on a hypothetical / deductive model where the experiment has the role of verifying or refuting a certain hypothesis. I use the term in a more general sense as a design project that intends to investigate and develop

certain aspects of the design process or that tests the unprecedented use of technologies or materials in design. Unlike the scientific experiment the design experiment does not validate repeatable universal laws but it seeks to contribute to the renewal of both process and output. Its primary aim is to contribute to methods and design discourse and only secondarily to reach finalised products.

Collaboration
In much of the work, active collaboration has been the main driving force. The framework that OCEAN NORTH provided was especially important in this. This mainly distant collaboration was essential for both the exchange of information and ideas, as well as for maintaining a creative environment for the experimental process. But even more significant was the co-operative strategy that was deliberately devised to prepare the ground for the unexpected by passing material on from one individual or group to the other during the design process. This special sequential type of collaboration was developed as a framework that would remain out of the control of singular individuals or groups. Instead we had to respond to and negotiate input from our collaborators.

The hybrid process
Digital design strategies are not seen as a replacement for traditional design processes but rather as a complement to these tools and techniques. The resulting hybrid process creates added value. The term *hybrid* is used in this thesis for a strategy that consciously seeks to draw on multiple processes be it the merging of processes, sequencing of processes, networking of processes or interdisciplinary teamwork.

1.2.2. The material

The examples presented in this thesis come from my own practice and teaching as well as from collaborative efforts in which I had an important role or where I had a first-person insight. In other words, where I have personal and first-hand knowledge about how the material was produced, which is an important aspect of grounding the results of this study.
The image material is credited to me if not otherwise mentioned. I have produced most of the images myself and they are as essential as the text for this thesis. The text would probably be incomprehensible without the image material. I use the images ostensively; the text points to the images that then hopefully clarify the text.

The images are produced over a time-span of 15 years. Some of the early images are of low resolution due to the lack of resources at the time. Some images from student representations are also low-resolution because the projects were presented entirely on the web. Also, some unavoidable

computer crashes occurred over the years that contributed to loss of data or recovery of low-resolution images only.

The images and other project documents are the main sources of empirical material. This supports the fact that the image material is not mere illustration of a text but it is equally important as the text itself. The thesis represents a 'meta-source', since it has been the main document of my thoughts about digital design for the last ten years.

I use my own material prolifically but use other image sources only very sparsely. Other architects and designers in the field are referred to, discussed and quoted in the text but their work does not appear as image material.

1.2.3. The framework of this thesis

This thesis concentrates on the initial phases of the design process. This is the stage where use of the computer is most underdeveloped, except for the experiments found within advanced architectural design where the computer has contributed to the altering of creative processes. The aim of this thesis is to look at these ways of working from the perspective of creative computer use.

Since we regard these techniques to be of a generic nature and applicable on any scale, this thesis draws examples from urban design, architectural design and object design.

Though the initial phases of the design process are in focus, this investigation also touches upon later phases where initial sketch material is developed further into more elaborated design suggestions. This is necessary to demonstrate the relevance and applicability of a suggested strategy.

The thesis emphasises the creative design process more as a process of generative visual and structural thinking than one based on expression, meaning, typology, symbols and semantics. I intend to demonstrate that structural and diagrammatical thinking is a powerful approach to the use of computers in the early phases of the design process.

This thesis argues for the need for abstract and diagrammatic thinking in exploiting graphical computing in creative processes. The term *abstract* is understood here as the rendering of unperceivable features of real-life phenomena, processes or forces. Abstract is not to be confused with the noun *"non-figurative"* which here is defined as not representing anything (l`art pour l`art). Figurative ways of working with the computer are of course of great value.

Most of our work as designers will be in figurative modes representing images and models of products and buildings. Representation of patterns of use, performance, relations and similar features are of an abstract nature which is best represented with diagrams. Much of the potential in creative computing lies in the representation of abstract elements structures and relations and in the recoding of data between diverse forms of representation. Through diagrammatic representation we analyse the structural features of real-life phenomena and the relations and forces between them. This implies the unfolding of events over time.

The initial stages of a visual and formal process imply the generation of new form. This thesis is focused on the generative aspects of treating formal, structural and diagrammatical issues.

2. Current State and Background

This section contains an overview and discussion of the field of the thesis. This field includes computer-aided design in architectural and industrial design. The discussion touches upon the most central theories and technologies that have been influential in the field. The main argument is that the development of digital tools is based on the continuation of an existing design process and on the restrictions given by the computer technology including programming processes. It is dominated by a perspective that favours concrete representations or simulations of real-world objects, rather than abstract systems, relations and forces as found in, for example, some scientific visualisation software. The idea of using software as an aid for visual thinking has not influenced the design of digital tools yet. Finally, I present what I call a 'misuse strategy' to overcome the lack of software especially designed for visual and spatial creativity. This strategy suggests the use of software for other purposes than what it was intended for

2.1. NEW TOOLS, OLD THOUGHTS.

Though software design is much more user-oriented than it used to be, it still has far to go when it comes to the creative user. Most designer software is made with either a focus on documentation or with a quite limited view on the design process. It reflects traditional working processes such as the use of icons that create associations to traditional design tools like pen and pencil in Photoshop. The development of design software has gone very slowly in the last five to ten years. It has been a period of refinement and consolidation. Software standards are becoming established and so is the way we use the software. Software engineers have their own distinct design methods and production culture, normally detached from insight into how designers work. (Beardon, 1999a)

Most 3D CAD and visualisation packages offer an extensive selection of tools. These tools are normally developed to construct already designed items. By this I mean that the tools and icons are designed for documentation and representation purposes and not for tentative creative and generative design phases. 3D libraries are constructed by mathematicians and engineers

to represent real-life objects; ray tracing and radiosity algorithms are designed to simulate real-life lighting and reflection phenomena; particle systems are made to construct and control fragmented and complex objects like falling water, hair blowing in the wind or swarms of animals. All off-the-shelf software is designed entirely for simulation and representation and consequently not for abstract generative purposes. It seems far more difficult to imagine abstract concepts meant for generative design strategies and to design software for that purpose.

When developing new functionality in a visualisation or CAD system, the programmer has to have an idea of what to achieve. It is far easier to program a clearly defined task such as a real-life representation of an object than to imagine the software been used in an abstract design technique. This might be a problem of lack of experience and sensibility on the part of the designer. Nevertheless, the software is designed according to quite restricted ideas about the creative design process. This may be partly due to the background of the software designers but it may also be a result of the inherent nature of programming. There is a genuine contradiction between the linear and fragmented workflow of the waterfall model for programming and the tentative explorative and heuristic nature of visual and spatial design processes (Balci, 2002). Other models of programming have been developed like RAD (Rapid Application Development) which is an iterative process. But still the programming process is (as far as I can tell from my very limited experience (basic and C++)) based on first setting a goal or imagining a function and then making it work. This becomes clear in a very interesting discussion between Kent Beck, known as the father of extreme programming (XP) and Alan Cooper a major proponent for interaction design. (Nelson, 2000) According to Cooper, interaction design addresses exactly the problem of the division between the thinking for software programming and thinking for human behaviour. Extreme programming addresses the problems following hierarchical organisation structures and ill-defined tasks. XP is a strategy for handling change during the process. This is achieved through frequent iterations e.g. numerous builds daily. (Compilation of code to test if it is working.) Still, I think the nature of programming is not explorative in the sense that it would be valuable to work in creative modes such as distracted or uncontrolled modes and analyse the results later. The reason is that there would be no results since programming demands clear plans on a short-term scale and total awareness to make things work. Malcolm McCullough describes the contradiction between the poetics of design and the rationality of computer programming:

> To realize the proposition of craft, we must also acknowledge that visual computing is far from mature, and that future software design must go deeper and strike better balances. For example, software designers should do more about reconciling direct within direct

actions, structure with improvisation, work with play, use with beauty. These combinations are worth pursuing, but to reach them will require going places where explicit software code cannot. Any better-balanced medium should approach our intelligence not only through formal logic, which computers perform better than humans, but also through visual insight, which humans perform better than computers. (McCullough, 1996)

Despite this quote being from 1996 it still seems relevant seen in the light of the discussion between Beck and Cooper. Cooper frequently stresses the need for visualisation of complex organisational issues ahead of the programming process. Still, computer technology seems to offer a vast unexploited potential of doing completely new things. But this exploration has to be done initially by the designer (interaction designers according to Cooper) with little help from programmers.

The dominating view of design as a problem-solving activity has moved attention away from the potential of visual computing. Most existing commercial systems are concerned with process management and cooperation rather than individual design processes. They are designed to manage the complexity in a process involving many participants. Examples are PDM (Product Data Management) in advanced CAD systems and PLM (Product Lifecycle Management) e.g. CATIA. The development of new concepts within visual computing has moved slowly. Both in 2D and 3D software the dominating principles are largely the same as 10 years ago. In 3D-systems we find still the same few ways of representing geometries (polygons, splines, rule based geometries[16]). Also the interfaces of the systems are slowly developing to become more similar, to make the move from one software package to the other easier. The concepts for building 3D geometries are very similar in, for example, different solids modellers (sweep, loft, extrude, protrusion, cut, rotation). This is partly a result of the mathematical libraries that are used in the software. There is only a limited number of ways to represent geometries and the same principles are used in most software.

Also, the parametric modelling engines are very similar and the principles implemented in design software today have been developed in the 1980s[17].

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[16] Rule based geometries are described by geometrical features. Typically a cylinder would be described by only three parameters: radius, sweep angel and height. A cylinder described with polygons contains hundreds of points with connected polygons but no parametric information about radius or height.
[17] Long-gone software like Anvil, which I used extensively in 1991 to 94, had all the advanced geometries including solids and NURBS, parametric features and scripting abilities we find in more modern software. The difference is the refinements and interfacing, but the principles are the same.

Recent developments indicate a new concept in the development of parametric design tools. One example is the 'Generative Components' tool by Bentley which seeks to bridge the gap between explicit modelling and parametric modelling, between visual design and programming and between software use and software development.

In scientific visualisation we can find models of process-based interfaces based on diagrammatic visualisation. Similar models of interfaces are found in musical composition software. They indicate other alternative ways of thinking about the interface for creative processes. These interfaces are time-based and diagrammatic and they produce an output that is changeable by adjusting variables.

MAX/MSP is a program for both sound processing and data control (either MIDI or abstract data used for controlling external devices.) The program shown in the below images was made by Natasha Barrett (
Figure 12, Figure 13). It involves live sound processing combined with prepared sound materials such that the composition is performed in 'real-time' - where the sound input is from an acoustic instrument, but the composition is not 'complete' until the sound has been processed by the different algorithms in the patch. This means that every performance is a little different, but the composer controls the main structure through having programmed the processing instructions and through having written a score for the performer to follow.

We can find similar graphic visualizations of relations and influences in parametric CAD tools. These devices may have the potential to be developed further and to be implemented in the visualization of networked processes.

Figure 12 A shot of the main screen of the MAX/MSP sound software. Each box contains a programmed patch. The main screen shows how the patches are connected in a hierarchy. This gives a graphic illustration of how different entities in a process influence each other. It is also a toll to organize and create these influences.

Figure 13 Each of the boxes that are connected together are in fact sub-patches The image shows the inside of the box "p live-processing", marked with an oval in Figure 12.

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2.1.1. New thoughts on existing tools

In this section I map new ideas for the design process that have appeared through my digital aided design work. Many of these concepts are based on the visualisation power of the computer. Visualisation is central to all of the concepts that are presented in this thesis. Visual creativity has so far not been seriously implemented in the digital tools we have at our disposal. The tools have been developed from more particular perspectives, where fragments of functionalities are added to meet specific demands and requirements in defined professions. But some specific strategies and techniques can push the use of software beyond the horizons of the programmers.

2.1.1. A misuse strategy

A central strategy to overcome the lack of creative approaches built into design software and to which we return frequently in this thesis is the use of software for purposes other than those they where intended for. The reason for this is that we find valuable alternative ways of using normal design software. By using software differently than originally intended we break the frames that are built into the software. We reinterpret the software.
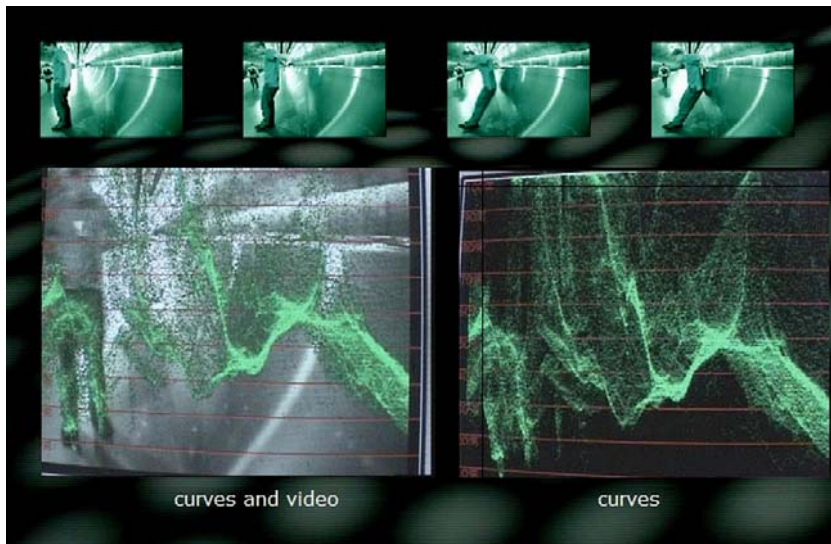
Figure 14 In a conceptual design project at the Oslo School of Architecture the students Jens Pettersen and Lars Bjerke used sound visualisation software in the process of designing a waiting area at a train station. The sound visualisation was merged with the colour level data from the video tape which created a pulse displayed on the shown screen. This merged visualisation of sound and visual elements of the site were used to produce a diagram of the sensory environment. Graphically displayed sound-waves could be used for the generation of spatial constructs (Figure 14). Colour depth can be used to inform spatial

depth or dynamics and inverse kinematics in animation software could be used for the representation of abstract and generative agents and forces instead of for the simulation of human skeletons (Figure 15) or the behaviour of real life objects in a space containing gravitation and wind-forces (Figure 16).
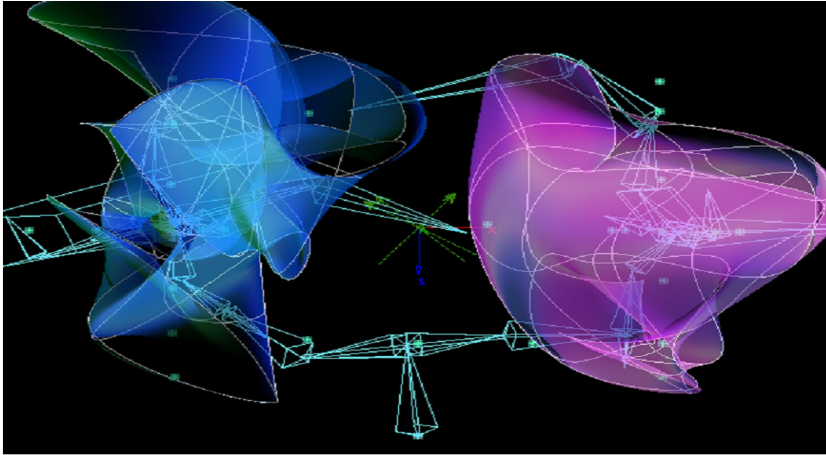
Figure 15 Inverse kinematics, a technique constructed for the animation of figures was used as a deforming device for the generation of two surfaces. (a_drift)

Other examples of misuse strategies that appear in this thesis are the use of flocking bird algorithms for the simulation of spatial agents that inform the design of an installation, and the use of scientific visualization software to visualize space in other ways than what is normally achieved with of-the-shelf CAD software. (Figure 17). The mentioned samples will be described in depth later.

The 'misuse' of software indicates a possible development for creative software in the future. New use of the software might lead to the rethinking of the design process and the invention of new types of spatial representation and software interfaces.
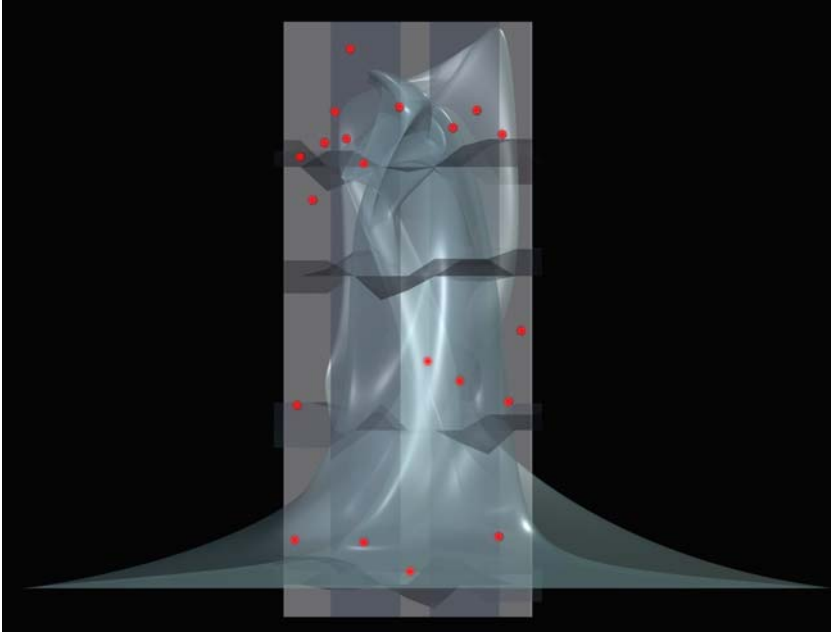
Figure 16 Dynamics used for the deformation of surfaces. The control vertices of the splines surfaces were anchored to the red spheres which were animated with forces normally used to simulate gravity and wind forces and modulated by adjusting the parameters that simulate material friction, mass and air-density. (World Centre for Human Concerns)

A 'misuse' strategy does not need to be as advanced and far-fetched as in the example in Figure 14. The use of animation software for the generation of form is an example where tools that were meant for presentation purposes in the final stages of a design process can be used in earlier creative phases of the design process. Design computing is a technology driven field were the technical possibilities are the driving forces for the development of new concepts for the design process. Emergence in design is a central aspect of this development.
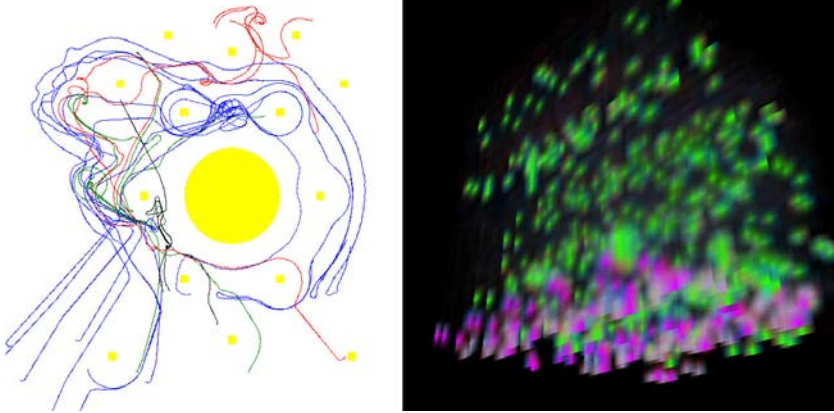
Figure 17 To the left: a flocking bird algorithm that was originally developed to simulate the behaviour of individuals within a flock is here used to simulate 'agents' or virtual personalities who move through a design space. The resulting tracks were used as design input for the AGORA installation. To the right: a screenshot of a three-dimensional voxel space visualized using scientific visualization software. In a voxel system every point in space is described with defined features. The voxel space is programmed as an experiment to exploit the voxel space for design purposes.

2.1.2. Emergence in design

Emergence is an expression that has made its way into design computing and it is both used and misused frequently. Emergence is used in design computing as well as in general with different meanings and interpretations. In everyday language it simply means to appear or to become (visible) (Cowie, 1989). A simple inclusive definition would be: The appearance of a novelty that is not obviously predictable or foreseeable. (Bullock et al., 1988) Emergence is used in system thinking in a slightly more complex way. This definition comes from one of the many online glossaries:

> Emergence: Synergetic and macroscopic phenomena of dynamical systems explained by collective and nonlinear interactions of their elements. (Taylor)

In design, the term is used in at least four different ways related to the above-mentioned definitions:

1. The use of a source material in the design process that dictates some of the conditions of the design process which will thereafter follow a path that is less controlled by the designer and from which the end result will eventually materialise and have an element of novelty and surprise.

2. The design of conditions for and according to emergence in urban or natural systems.
3. The use of emergence in material systems, how materials self-organise into structures.
4. Computer simulated emergence, like self-organising architecture or genetic algorithms, cellular automata or self-organising and self-growing architecture.

We will return to these descriptions of emergence in the next chapter. For now I will try to provide a simple explanation of why emergence is so closely tied to design computing and how it may have triggered a new way of designing. This explanation follows the same line of thinking as the first explanation, the use of source material that directs a process into a partly uncontrolled mode. This approach has been explored by electronic artists for a long time.

Many advanced users of 3D-systems have a quite realistic view of the computer's advantages and disadvantages. Most designers and architects using 3D design tools are aware of the limitations. Pen and paper are quicker, simpler and in some regards better suited for spontaneous sketching. The computer is normally not a spontaneous tool (except for drawing pad systems like Wacom). The computer's advantages when it comes to creative design methods are found elsewhere. An important characteristic of the computer is its ability to handle complex data. The design data can be interlinked into complex systems that interact when we alter a single element in the system. The given example is very simple: In an architectural design we could define the relation between the widths of the window frames in a big building and the distance between those frames and describe it as a parameter. On altering this parameter, the whole facade would reorganise into a new pattern of distribution. The systems can become much more sophisticated when connecting other data like the distribution of panelling of the facade or the relation to other possible building elements. The regeneration of the output is automated. We cannot predict all the consequences of altering one parameter in such a system and the response of the system to our tweaking is sometimes surprising. It emerges from the interplay of the complex relations in the system.

Another source for our belief in the potential of the computer as a creative tool has been the errors or coincidental effects we stumble over during our work. (Beardon, 1999a) The computer produces unanticipated emergent forms that we might find inspiring and sometimes useful as source material for design. This was especially obvious in spline-based software. While the CAD-industry spends much energy on removing such errors, in the early days when spline-based software became accessible, the errors triggered a playful investigation into the features and possibilities of those geometries.

This investigation consequently reached a stage where these errors where controlled by the set-up of complex animated systems that would produce unexpected forms. The forms emerged from a complex system that was partly unpredictable.

We face several problems when we try to utilise unanticipated output from the computer. We don't accept accidental results because they emerge without the control of the designer. The appliance of emergent methods contradicts the myth of the designer as an especially talented person who has undergone specific training. A spread belief about creativity is that it basically comes from an internal cognitive or tacit process. Many people also appreciate the external social and environmental aspects of creativity. (Sternberg and Lubart, 1999) But the computer as a tool for supporting creativity does not somehow fit into this. We think of the utilisation of emergent material as cheating.[18] This is a misinterpretation. On the contrary, the advanced design methods that have developed from the conceptual use of computer technology demand a high level of talent and a wide range of skills. These skills span from conceptual thinking to visual creativity and the capacity and stamina to carry out large and tedious work processes.

Another problem is that the material resulting from the computerised emergent process has no meaning since it does not necessarily represent anything. Many designers are brought up on design processes that start with the formulation of a goal. This goal is kept more-or-less in focus throughout the whole process. There is little room for allowing responses that would lead to totally different ends than those imagined. This is of course legitimate in a hectic practice where deadlines have to be met and customers have to be satisfied. But if we want to work in more experimental modes, it is often better to work in an explorative way. An efficient mode of experimentation for a designer is the iterative process where we can respond to intermediate results and alter the means of investigation in steps.

The emergent material does not represent anything other than structure and visual beauty. To use emergent material in a design process we need to know how to operate with abstraction and non-representation. We need to adopt what modern art did many years ago, namely to regard the visual material as *"Das Ding an Sich".* This corresponds to the idea of "*l'art pour l'art"* in the modern art movement. The lack of such an ability of non-figurative visual thinking is a major hindrance to using unanticipated emergent material in design.

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[18] Nørretranders mentions several examples of the feeling of cheating when any skilled person experiences to perform well without mental control. (Nørretranders, 1991)

If we want to exploit the use of the computer as a machine for an emergence process we need new methods that include both computer technology and human creativity. We need to know how to produce emergent material, develop it further and translate it into new forms, digital or physical. Then we need to develop strategies and techniques to balance between controlled design and emergence. One of my main issues is a quest to develop techniques to balance design intentions with the emergence of the computer, to balance control with surprise in order to create valuable output.

The use of the computer with such intentions is somehow a self-contradiction. On the one hand, the advanced utilisation of software such that new results emerge demands a high degree of control. On the other hand, the emergence of new results is always relative to what is anticipated. Explorations of possibilities through emergent processes based on complex computation always imply an element of surprise. Emergent design implies anticipation and surprise otherwise it would be just another linear process where a certain goal is fixed and eventually reached.

2.1.3. Programming and design

Some artists and designers are also programmers. Programming skills are of course an advantage for designers. But referring to the issues of programming I touched upon in the previous chapter, there are certain difficulties in developing the creative design process towards new areas through programming. The main reason for this is that programming builds more on cognition and verbalisation than on visual thinking. Casey Reas[19] believes that programming contradicts a spontaneous creative process because of its time-consuming nature. People like Casey Reas are creative people working in a media that does not support visual creativity directly, but they find a synergy since they are highly trained in both skills.

The designer may be seen to have little in common with software engineering and programming. Casey Reas suggests another perspective. He looks at the matter in degrees of computer literacy when he states that most digital artists program with high-level software (e.g. Flash) giving high accessibility while only few use generic programming languages (e.g. C or Perl) (Reas, 2003). Casey Reas states:

> There is no correct way to work with software. It is an individual
> choice balancing control with simplicity. Mastering programming

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[19] Casey Reas is a graphic designer and programmer who has been teaching at IVREA and many other prominent design educations. He is the co-author with Ben Fry of the software Processing a script based learning environment for motion graphics (http://processing.org)

takes many years of hard work, but understanding the basic principles of the medium is within everyone's grasp.

Natasha Barrett[20], a contemporary electro-acoustic composer with whom I have been working on several projects has a nuanced view of programming versus using commercial software where the restrictions in the software can actually be beneficial:

> The processing options available range from the use of commercial software where the user can change a few parameters in the algorithm, to the user programming their own transformation software. The former places a restraint such that it reduces what can be controlled (to some extent useful because it means that the composer is not faced with an infinite set of choices). The latter allows the user complete flexibility, particularly in the feedback process, but having such control over the process can interfere with the mechanism of surprise, emergence and discovering.

Later she launches an argument for programming versus commercial software:

> -- the use of commercial software can lead to your experiments being very similar to someone else's, and when two people have the same background, training, ideas and environment, their creative processes and their results can sound very similar. Programming your own algorithms can avoid this danger by virtue of the advantages of custom-made programmes mentioned above. (Barrett, 2004)

One could imagine future design training where traditional designer skills such as drawing techniques are replaced with programming courses. But so far this has not happened. On the contrary, at AHO at the Institute of Industrial Design traditional drawing skills have had a renaissance since around 1997 when a conscious decision was made to foster these skills but simultaneously develop the curriculum of design computing further. The decision has so far proved to be right since it produces more competitive designers all having a fairly high level of computer skills when it comes to normal design software and some of them achieving additional skills in programming on an individual basis or through taught courses in interaction design.

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[20] Natasha Barrett is an English composer based in Oslo and member of the organization NOTAM a collaboration of electronic and contemporary composers and musicians. She has won several international and national prices for her compositions and installations. She was initiating our collaboration in the AGORA projects.

This is about to change. In interaction design the need for high level scripting skills is obvious, but also in industrial design and architecture the pressure to master a certain level of scripting is increasing. Popular animation tools like Maya or 3DSMax do have advanced scripting features. The CAD software becomes increasingly demanding when it comes to handling project data. Recently, a few attempts have been made to bridge the gap between designing and programming. Casey Reas is one of the creators of the software 'Processing'[21]. This software is especially written to learn and teach programming of motion graphics to designers. Reas thinks that this is just the beginning of a future development where different levels of programming will be fully integrated into the design process and design software:

> Over the last thirty years, artists have created innovative work with the aid of the software medium, but they have explored only a small range of the conceptual possibilities. Historically, programming languages and environments encouraged a specific methodology that did not engage the majority of artists who were interested in creating interactive and programmatic work. New tools are emerging that encourage artists to begin working directly with the software medium. The proliferation of software literacy among artists will increase the sophisticated use of software and contribute to new forms of software materials and development environments. These materials and environments have the potential to open the creation of software to an even larger creative and critical community. (Reas, 2003)

Another example is the aforementioned 'Generative Components' from Bentley, an interesting attempt to create software for the programming architects:

> Generative Components is a model-oriented design and programming environment which combines direct interactive manipulation design methods based on feature modeling and constraints, with visual and traditional programming techniques and represents Bentley's response to the requirement for a "programmatic design" environment that is a fusion of geometric modeling and software development. What we are searching for in the development of Generative Components is the minimal abstraction of design, that when implemented in software and used by creative designers, provides for the most expressability, the most extensibility. (Hesselgren et al., 2003 -)

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[21] Processing is a programming environment for exploring the emerging conceptual space enabled by electronic media. It is an environment for learning the fundamentals of computer programming within the context of the electronic arts and it is an electronic sketchbook for developing ideas. (Reas, 2002)

This ambitious project is still based on traditional geometries and spatial descriptions, but the framework is altered. It suggests a designer who also has a certain degree of programming skills and who is participating in a network interacting with a certain company's software developers. This is organized through the Smart Geometry Group[22] which provides both a networking and learning environment. This intelligent approach takes into account that the use of software is not only a question of software features but also of the knowledge and intentions of the user community.

2.1.4. Artificial intelligence

The research of Artificial Intelligence (AI) in design has gone on for many years. Especially in planning it has been pushed forward in so-called Expert Systems. But in creative design, AI has only been used sporadically. An important criticism against the use of AI in design systems is that they "bypass" human creativity. This criticism might be just regarding the speculations of entirely independent systems suggested by e.g. John Frazer (Frazer, 1995).

But problems arise mainly when we attempt to completely leave out human intelligence. As long as we regard the systems as helping devices for our design processes we can intervene at any point and take control. Systems which are specialised to solve certain tasks and which could be influenced by the designer are more likely to be used, though this still leaves some questions open when it comes to the implementation in real projects. One such example is the work of Kristina Shea, who has developed a system based on shape-grammar for the generation of space frames. (Shea, 2004)

2.1.5. Human intelligence and artificial representations

This thesis argues for the development and study of techniques that are based on man-machine interaction. These encourage the playful adaptation and redefinition of any rule of the game, combined with rigorous investigation. This approach implies that generative material (including genetic algorithms) is processed and modified through an extensive design process. In such a process it is also important to consider what the material represents. The material will during such a process change in meaning and representation. Initially representing nothing (l'art pour l'art), smoothly developing throughout the design process via representation of abstract generative forces to suggestions of the organisation of spatial features or events until reaching a stage where the material develops into the representation of objects, buildings or systems.

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[22] http://www.smartgeometry.com/

The approach implies recoding of input and output. Recoding means 'changing the form in which information is stored' (Gleitman et al., 1999). The approach is also driven by experimentation with a wide range of software that is not necessarily used in the way it was intended, the 'misuse strategy'.

These methods are reproducible by any designer, even those without programming skills as long as they have average software skills. Eventually over time this approach may allow the development of new ways of working and as our understanding of these ways increase, we will be able to develop software based on that knowledge.

2.2. ELECTRONIC DREAMS

Expectations and myths thrive under the influence of digital technology. Digital technology is inspiring and triggers our fantasy and makes us dream about its potentials for the future.

Computer technology has created its own myths about creativity and design work. In the 1980s the first ray-traced images were published leaving the design community in astonishment. This was the start of dreams about what computers could do for visual creativity, but there was little mention of the laborious hours needed for implementation and preparation, nor of the costs involved.

The promises and visions of working digitally have to a large degree been fulfilled when it comes to graphical design, a profession that has been altered dramatically through digital technology. The computer has radically improved the speed of working, converting processes that used to be painstaking and time-consuming, into quick and playful sessions. The technology has radically changed the products. Combination of images, filtering and drawing techniques that were unthinkable before are applied everywhere, even on an amateur level. Motion graphics are amongst the most advanced examples of this development.

In graphic design, the actual outcome of the process has been changed since the designer now forms the final production material directly, and the industry has totally adapted to digitally driven processes. In physical design, the designer almost always works with a distant representation of the final product. The route from the designer's computer to the final manufacturing data is more complex and involves more complex expertise than in graphic design. In industrial production a revolution has taken place with robotic manufacturing. There is no longer any clear distinction between the designer's material and the information needed for manufacture.

The shortened distance from the designer's file to the production tools promise a future of automation in design processes. Rapid Prototyping, slowly developing into Rapid Manufacturing forecast future production processes that will alter the way we work as designers. (Killi, 2005)

2.2.1. The dream of intuitive software

Also when it comes to software use, the situation differs between graphic design and 3D design. Graphical design tools are very easy to learn and intuitive to operate compared with 3D-software. There have been virtually no radical new inventions in the mathematical representation of 3D geometries during the last ten years. The mathematical principles that are used to define the geometric libraries are not very intuitive.

A primary goal of producers of CAD software is to make the software easier to use and to overcome the difficulties that result from the way the software represents geometries. This is done through developing the mathematics so that it is able to handle difficult situations better and through developing better interfaces. Already in 1996, Malcolm MacCullough discusses the problems connected to the development of so-called intuitive software seen in relation to traditional crafts. (McCullough, 1996) He states that there still is a long way to go and that the key is visual thinking. Nothing much has changed since then and his points are still relevant. McCullough compares the computer with the tools of craftsmen. Whereas the form and use of these tools has developed over many years, the computer has still not reached a similar level of development. He suggests that the visual codes and metaphors themselves should become objects of craft. The metaphor of an ancient traditional craft is intriguing and has the potential to contribute to the development of software. But this approach to computer-enhanced design also has its limitations. The development of workmanship took a long time and the evolution of this kind of skill was a result of pre-industrial production, where knowledge and skills were protected by monasteries and guilds and passed on from generation to generation. The computerised "craft" developed from a very different set of conditions.

Another point which makes the comparison difficult is the question of intuition and spontaneity in the application of traditional drawing tools. For an untrained user these tools are very awkward to use. It takes many years of training to achieve skills that allow for fluency in the work and additional training to present accurate representations that communicate well with others. I have not found any study on the comparison of learning curves between traditional drawing techniques and graphical computing, but I suggest that such a comparison would favour graphical computing.

Nevertheless, McCullough points to a very central aspect of graphical computing. Skill developed through experience is far more important than training in specific software. This generic skill develops an intuition for problem-solving, for walking around obstacles, for adjusting to the endless stream of new software. Children who grow up with computers develop an intuition for handling the computer. Computational intuition is an experience-based skill, only achievable through practice.

While the pre-industrial craftsmen specialised in a limited selection of tools, the contemporary designer adapts constantly to new software. The craftsman learned the nuances and secret tacit knowledge of handling the tools. It took years of training and specialisation to achieve mastery. It takes years as well for the modern "craftsmen" of digital design, but the knowledge and skills are of a different kind. This kind of knowledge is about developing an instinct for solving problems, bouncing between different software tools and techniques, playing with and not against the technology.

In modern 3D design software, we can hardly see any remains of the craftsmen's tools. Only in the interfaces can we find icons referring to the physical tools. In graphic design we also find the only really successful attempts to digitise traditional physical tools, the pen pad (Wacom). The connection of a traditional tool to a computer reinvents the traditional tool, widens its application and increases its usability. The pen pad is in fact a traditional tool connected to the computer, converting a traditional drawing tool into a flexible human - computer interface. Similar tools for 3D like the Microscribe, which in fact operates like a 3D-mouse, and the PHANTOM® Omni™ Haptic Device[23] which directly simulates sculptors' tools including force feedback, have not had the same success as the drawing pads. These interfaces make modelling intuitive. Despite this they are not widespread.

The mouse, the new tool of the computer age, is a genuine new physical input device creating an analogue connection between physical input and what is seen in real-time on the screen. The mouse is universally adaptable and relatively easy to learn to operate, though it lacks the accuracy and tactility to qualify for a tool that would be of benefit in a crafts-based working process. Some attempts in this direction have been made, mainly involving the manipulation of camera positions, but these are also rare in use. In gaming, similar devices are far more widespread, like joysticks for PC-games and special interfaces for game consoles. These are intuitive tactile devices with simple force feedback, intensifying the immersion into the games. The players operate these devices in a way that rewards skill gained through experience, similar to traditional physical tools.

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[23] www.sensable.com

Whether similar devices will appear in design software remains to be seen. I think this would require a total rethinking of the mathematical representation of geometries in CAD software.

The commonest tool remains the mouse operating the icon-based interface. The icons in 3D software are quite abstract, relating to the mathematics of the software, though we can find terms that refer to mechanical production processes like cutting or protrusions. In design software, the use of metaphors should rather be seen as one of many layers and modes of communication (Human Computer Interface), than as a parallel to an older craft. The modern computer-user applies new software directly, learning only as much as is needed from any software on the fly. The use of metaphors in computers is only justified through the need to use the tools immediately, without any former tutoring or additional explanation. Thus we know that if we virtually "push" a button on the screen by superimposing a cursor on it and clicking the mouse button this will lead to an action. If this button has an icon that shows a pen, we know that this function is used to distribute and alter the colouring of pixels on our screen in a similar way to drawing with a pen on paper. The function is represented and designed according to a metaphor, with no other intention or purpose other than communicating how the virtual tool works. The icon that shows a spray can represents the virtual tool that applies colour in a way similar to an airbrush but also with big differences. Using a paint spray is a highly specialised skill, which demands quite a bit of practice. This type of workmanship is quite remote from the use of the spray can icon controlled with a clumsy mouse. In other words, the similarity to traditional tools serves other purposes than bringing the traditional skills into the computer-aided working process. The icons referring to traditional tools are meant to produce a recognisable environment for the user, nothing else.

McCullough's craft oriented approach is important though limited.[24] The digital aided design process is less dependent on manual skill than earlier crafts and more dependent on the development of a new skill, computational intuition. It is more dependent on the ability to absorb potential possibilities offered by the technology. It is also more demanding when it comes to understanding modes of representation. Perception, intellectual skills and the learning of processes and manipulation techniques are far more important than they used to be. In the future, we can imagine different types of creativity enhancing machines, like communication-based artificial intelligence or abstract visual approaches, the latter being the particular focus of this thesis.

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[24] Though McCullough treats the theme in a wide and inclusive way, elaborating on many aspects of visual computing the focus is on a manual hands-on work process.

The design of intuitive Graphical User Interfaces (GUI) makes it possible to use software without learning it in advance or with as little help as possible. The software should be self-explanatory so that whenever the user faces a problem it should be solved through intuitive trial. Also the software should be as un-disturbing and "smooth" to the creative process as a pencil is to the very skilled artist.

The software is designed to be easy to learn, intuitive and recognisable through the use of metaphors and conventions. Metaphors of traditional real-life tools are applied to everything from general buttons to icons for different paint tools in paint software, where the icons not only represent a metaphor but where the tools are based on virtual simulations of traditional tools.

Several different concepts are applied to come as close as possible to this ideal. In 2D graphical pixel based software like "Photoshop" the tools and their icons are designed as metaphorical variants of real-life tools. This ideology takes for granted that the existing drawing and painting tools correspond to a static working method within graphical design. Computer technology is applied to this method to enhance it and increase production speed and add a few extra possibilities.

In 3D software it is difficult to use direct metaphors since the mathematics of 3D objects is based on concepts very alien to crafting. The icons in 3D software are designed to visualise the way those tools are used and not as metaphors of real-life sculpting tools.

Another concept to help the user to decrease time spent on learning how to use the software is to establish conventions. (Sheppard, 1987) These conventions make it easy to transfer skills learned in one software program to another. Basic operations, like how to store files or copy and paste, only have to be learned once. Also the general structure of the GUI has developed into a *de facto* standard.

A third concept is to make the software features and parameters accessible and controllable through direct analogue and self-explanatory access. Buttons are used to communicate with the software and to confirm choices. Sliders are used to fine-tune parameters.

All these different concepts result in quick learning curves for beginners. The modern computer user makes use of a large number of software packages.[25]

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[25] McCullough describes how this influences the design process: ....*interactive computing invites a reflex-based kind of activity often difficult to reconcile with thoughtful planned work. Computers fragment our thinking by substituting discrete*

The typical way of learning is not through coursing but through trial and error. Such users only know a limited selection of functions in each software package, a selection based on the user's individual needs. This modern case-driven approach to computing is possible because of the aforementioned concepts, conventions and self-explanatory GUIs. Conventions and metaphors make it possible to approach new software though trial and error or intuitive search for the right operations.

The self-explanatory, quick-to-learn GUI does not necessarily result in user-friendly software in the long-term. To understand these mechanisms better, we have to sort out some confusion in how we understand intuition and spontaneity. Intuitive decision-making can be used after thorough considerations and in situations when there is time to investigate different solutions. Intuition is to make choices based on your gut feeling. Intuitive choices are always based on pre-existing knowledge.

Spontaneous choices and decisions are less based on conscious pre-considerations or knowledge, but more on subconscious reflexes modified through repetitive rehearsing. This should be considered carefully because, although a software package with a modern GUI can be highly intuitive to use, it is not necessarily used spontaneously. When people refer to intuitive software, they tend to talk about spontaneity in the design process. As already mentioned, spontaneity is based on reflexes modified through repetitive training. To react spontaneously there must be a framework and a set of possible reactions. The framework is conserving. We need this kind of spontaneity in creative work. It is what we use when we are really trained and skilful. For example, a musician can only improvise within the freedom that is given by a certain framework. And the musician needs years of training before achieving a level of skill that allows for spontaneous improvisation. (Ghiselin, 1952, Nørretranders, 1991) This type of spontaneity is good for highly specialised activities. But the computer is a generic machine allowing and inviting the implementation of a range of different ways of working constantly demanding the creation and definitions of new frameworks.

Moreover, this is not necessarily the type of spontaneity we have in mind when we talk of intuitive software, but rather the ability to have an uninterrupted workflow, allowing a smooth flow of visual thinking. Visual thinking can be applied both during and within the process but also for a post analysis. I think that this need for spontaneous software is over-exaggerated. What we need is what I like to call 'systematic intuition'. We can train intuition systematically to move into new fields. This training is based on

events for continuous actions, and requiring us to learn a bewildering multiplicity of processes. p.53 (McCullough, 1996)

selective knowledge-accumulation and can enable us to move into totally
new ways of using the computer in the design process.
(More about visual thinking in part 3)

2.2.2. The dream of the designing machine

The computer technology has always triggered our fantasy. Some times this
results in rather unrealistic dreams of what the intelligent machine can do for
us.

Artificial intelligence in design

Artificial Intelligence has never quite made it into design[26]. This kind of
research seeks to use the computer's logistical capability to aid the solving of
complex problems. This research seems to advance slowly. Its limitations are
that it mostly addresses the problem-solving logistic parts of the design
process. Problem-oriented logistics are based on pre-conceived rules,
intending to simulate the way experts negotiate solutions. In a typical
building design process, there could be a different agent for each of the
engineering professions involved. One agent would represent electrical
systems and wiring, there would be a ventilation agent, one for fire security
etc. Whenever the agents run into conflicting situations they would negotiate
according to certain rules. Typically these rules would prevent a less crucial
agent to over rule a more important one. The way in which such systems
negotiate a conflict between construction costs and design intentions is not
very encouraging. Human intelligence has the ability to produce genuine
solutions that solve such conflicts in a synergetic way. How we actually do
this is unclear and far removed from the way such matters are implemented
in artificial systems. Expert systems still have severe limitations. They are
limited to following the rules of the game and do not have the capacity to
come up with new principles. I suggest that the best innovative solutions
come up through breaking such rules. Often innovative rule-breaking
solutions are simpler and more economic than more conservative ones. Also
in the solving of logistical problems unexpected solutions can come from the
merging of these problem-sets with others such as aesthetical ones. In the
programming of the expert system, the system engineer can hardly avoid
imposing his or her conception of design schemata. But more important, the
systems are designed on the basis of certain categories, rules and schemata.
This is implicit to the nature of programming. New approaches which include
the integration of scripting and partial programming for the user and which

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[26] Artificial Intelligence in design has been discussed by people like
(Beardon, 1994, Beardon, 1995, Kelly, 1994, Turkle, 1995, Casti, 1997,
Spiller, 1998, McCullough, 1996).

negotiate the relation between the user and software design facilitates, enable the software to remain 'part-open' thereby overcoming the schematic and preconceived use of the software. One such program is Genr8 which is a 'programmed' tool that combines an evolutionary algorithm and a growth algorithm. A general set of rules is established, however, specific constraints for each output need to be defined within this framework.

The creative human has an ability to break the inherent rules of usage of the software and replace them with others at any time during the design process. Humans can also recognise the need for new categories and schemes and the relations between them and generate these on the fly. This ability is crucial to the design process. So far AI has not been able to simulate this ability. Also the appliance of neural systems with the capability to "learn" has limitations. These systems are dependent on repetitive patterns of behaviour, which is a conserving feature. Humans are able to recognise the unique opportunities and learn from singular cases. As yet, there is no AI system that is able to break schemata in other than a random and therefore useless way. Breaking the rules is, in itself, not difficult. If we define creativity as being original and useful, the trick is to break established rules in a way that eventually is beneficial. (What is beneficial, needs to be described in each case and relative to a given intention)

Research in artificial intelligence applied to design problems suffers most of all from lack of appeal. AI research in the area of design should focus less on replacement of human intelligence and more on playing up to and communicating with human intelligence. AI concepts from computer games could possibly inspire such a way of thinking. Software could be developed where responsive environments could be exposed to similar simulations as in computer games. There is still a long way to go.

2.2.3. The dream of self-emerging architecture; genetic algorithms in design

A few architects have since the eighties worked along the path of self-emerging architecture. Genetic algorithms first applied to art by Latham were later used for the generation of architectural space by John Fraser.[27] Though this line has continued with Karl Chu, the concept of self-emerging architecture seems to remain in a highly hypothetical state. The problem with genetic form in general is its tendency to repetition and the failure of introduction of *fundamental* change through mutation. Though they might be beautiful at first sight, they all operate within narrow fields of formal types, which rapidly exhaust their potential of variation.

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[27] Genetic algorithms in the design of environments have been treated by e.g. (Chu, 1998, Frazer, 1995, Turkle, 1995, King, 1997)

Manuel DeLanda points to this problem in his article on Genetic Algorithms (DeLanda, 2002):

> When one looks at current artistic results, the most striking fact is that once a few interesting forms have been generated, the evolutionary process seems to run out of possibilities. New forms do continue to emerge, but they seem too close to the original ones, as if the space of possible designs, which the process explores, has been exhausted. (p.11)

Genetic art and architecture are of course also a result of human creation both in the design of the initial algorithm and set-up, and in the presentation of the results which are subject to aesthetic modifications. Especially in the final representation and visualisation there are many possible choices. Ultimately, the algorithms and their calculated constructs are merely bits and bites. The way they are visualised is subject to interpretation and aesthetic choice. This is especially obvious in Latham's work. (Kelly, 1996)

DeLanda puts it this way:

> Will the future authors be content in the role of form breeders? Not that the process, thus far, is routine in any sense. After all, the original CAD model must be endowed with mutation points at just the right places. This involves design decisions and much creativity will still be needed to link ornamental and structural elements in just the right way. Nevertheless, this remains far from a design process by which one develops a unique style (p.11).

DeLanda's argument is relevant when applied to extensive automation in a design process. But an obvious way of overcoming this potential weakness is negotiating self-generation with other modes of creation. When working with generative design techniques the designer eventually develops a new sensibility and new ways of strategising and integrating the computer generated results. This would include the integration of spatial strategies and material constraints into the setup from the beginning. It would also include the development of a sensibility for visual analyses and mediation strategies for the development of the project all the way towards realisation.

2.2.4. A cultural lag

Designers are generally not well tuned in to the cultural developments in electronic arts where we to my mind find the most radical experimentation with digital technology. According to McCullough this is due to a cultural lag based on generation shifts where new technologies are only adapted after a certain time and by new generations of designers. But there is an additional

explanation to be found in the absence of experimental design in design culture, especially in industrial design. In this area, the design community has a lot to learn from the electronic arts. As cultural, technological and economical changes accelerate, it is important to investigate new technologies and possibilities as quickly as possible. If the designer wants to stay in the forefront of these fluid conditions, he or she has to be willing to experiment with new media.

Design methodology seems to take on a defensive attitude to new technology and the cultural changes that follow it.[28] Though a lot of researchers are engaged in computer technology, almost all research is focused on adapting the technology to the way designers work. Several different areas of research can be found:

- Research on artificial intelligence,
- Research on the development of intuitive user interfaces. (Ergonomics)
- Research on what architecture could be in the new "virtual age" (Multi media architecture) (Allen, 1999a)

There is little done to adapt design methods to the new technology. Malcolm McCullough describes this situation as 'cultural lag':

> "New thinking and new tools may go together, but only rarely are an altogether new tool and an altogether new task invented simultaneously…. ….Usually a new tool is used to do things pretty much as they always had been done; usually a new task is done quite some time by means of adapting existing technology." (McCullough, 1996)

There are a few examples of architects who have altered their design methods on the basis of computer technology. But such architects, (like Greg Lynn), do not define their work first of all as research in design methodology as such. Though they are deeply involved in the development of new design techniques and strategies, their ideological base is more in architectural theory informed by philosophy than in methodology.

Other architects like Peter Eisenman follow similar paths, not necessarily embedded in computer technology, but developing design techniques highly adequate and easily adaptable to the use of computers. The core issue in this is abstract and diagrammatic thinking.

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[28] See Sanford Kwinters essay "The Genealogy of Models: The Hammer and the Song" for a critique of resent understanding of diagrammatic thinking in design. (Kwinter, 1999)

Stan Allen points to the reinvention of the diagram as a means of revitalising the design process:

> Diagrams are not schemas, types, formal paradigms, or other regulation devices, but simply placeholders, instructions for action, or contingent descriptions of possible formal configurations. They work as abstract machines and do not resemble what they produce. (Allen, 1999a)

2.3. IDEAS AND IDEOLOGY

The development of radical computer-use has been largely influenced by an ideology brought forward by a group of architects that Ali Rahim calls the *neo-avant-garde.* The term avant-garde refers to the innovative modernist movement of the first half of the twentieth century. Ali Rahim argues that we today can speak of a neo-avant-garde emerging from digital culture that drives the generation of new concepts, ideas, solutions and technologies in a similar manner as in the days of the avant-garde. I use the term here to further emphasise the importance of the state of the field and the conditions of the domain to promote individual creativity.

Creativity thrives best in a context where experimental ideas and theories are shared. Designers benefit from participating in the most informed discussions, keeping up to date on the most recent ideas and theories occurring in the field, and practicing the most up-to-date techniques. Creative people benefit from being a part of the avant-garde.

In this context, the notion of the avant-garde is used in its widest sense. The term is used for cultural movements that have an element of innovation. Designers need such responsive environments where they can find support and discussion that make them perform better.

According to Charles Jencks' diagram of movements in modern architecture, various theories overlap, move in parallel or succeed each other. (Jencks, 1985) These theories, many of them short lived, do not declining because they are proven to be wrong but because they quickly lose their potential to support adequate action. The potential for being creative is exhausted the moment the theories stagnate and young architects move on to the next context that will provide them with the best climate for being an experimental architect.[29]

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[29] This relates to Kuhns theory on paradigms in science.

The works presented in this thesis have been produced in a context of experimental design where response and recognition from the international community has been important.[30]

2.3.1. A personal perspective on the theories of the 1990s

This is not an actual description of what the philosophers represent but a description of how I became inspired by the philosophy in architectural debate.

The thoughts that were the most inspiring for me were the concepts of forces communicated into design by people like Eisenman, Kwinter, Massumi, DeLanda and others, who were influenced by Deleuze and Guattari reading Leibnitz and Foucault . These turn our focus towards the forces at play in the world and the relations between them. The central notion of this was a redefinition of the diagram depicting the "Abstract Machine" This concept was very liberating to me for two reasons:

1) It manifested a departure from fragmentation which I think was the main aspect of post modernism, including deconstruction. The "Abstract Machine" re-established my belief that it is possible to design with a complex world in mind. Planning again made sense but a new way of planning, a way of dealing with uncertainties and indeterminate futures. Planning for the dynamics of the real world became feasible.

2) The diagram as "Abstract Machine" - a play of forces, a dynamic device was perfectly suited to the computer. It opens up and releases the potential of the computer as a design tool. The idea of the abstract machine is based on the assumption of the existence of abstract diagrammatic forces existing independent of human perception. These diagrammatic forces are addressed in the design process.

We can find the philosophical base for this theory in Anne Conway's and Leibnitz monadic theory (Stigen, 1992) p 479. Leibnitz rejects the thought of space as anything but a result of the way we percept reality. The only things that really exist according to Leibnitz are forces with no dimensions. The world consists of force units, which exist separately, and independently. These force units Conway called monads (from Greek Monas: unit).

This theory is rather cryptic but, through the interpretation of Deleuze and others, it contributed to forming a philosophical base for planning in a

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[30] The people OCEAN NORTH have been in a constant dialogue with the most recognised architects in the field on an individual level and through common publications. This has had a great impact on the group.

dynamic world. We started to look upon the world as a dynamic place where everything is in motion, and where what seems stable is actually moving so slowly that we perceive it as still. All the forces in nature or human systems interact and influence each other, forming the world as a complex dynamic system. In terms of the state of the ecological systems of earth, it becomes increasingly crucial to understand, monitor and softly tweak these systems.

The theory of forces has through Deleuze and Guattari inspired a new generation of architects and revitalised the belief that architecture can relate to its surroundings despite its complexity. But as earlier architects tried to relate to real-life in a causal (functionalistic, cause - effect) way, the abstract diagrammatical approach does this in a more tentative, suggestive, speculative and adaptable way based on exchange of fluid interconnected forces over time. The logic expansion of this focus on dynamic forces in the design process is an interest in generative design and emergence as a phenomenon.

The models of cause - effect can also be seen as a way of isolating the causes and looking at the world in fractions, while the abstract diagram can be seen as an attempt to monitor and understand complex processes in a holistic perspective. In this perspective, prediction derived from the cause - effect model is regarded to be only applicable in very specific cases under experimental conditions, while the holistic approach, dealing with a very high level of complexity in real-life systems, prefers to operate with speculations about possible behaviours of the systems than with predictions that can be tested under laboratory conditions.[31] Chaos theory has demonstrated that even simple systems can produce output that is non-repetitive and unpredictable in detail, but can only be predicted on the level of large-scale patterns (Gleick). In addition, social and technological developments have reached a stage that demands new ways of responding to systems behaviour (Kelly, 1994).

The forces we treat diagrammatically in the design process are to be understood more in the sense of information flow than mechanical forces as such. The approach is articulated, though flexible and it plays up to the social, cultural, economic and ecologic forces engaged by the architectural intervention. The monitoring, analysis and modification of time-based processes plays a central role since the interplay of forces unfolds over time.

Two other themes from recent architectural discourse have special relations to the current practice of generative computer-aided design and animation in design: folding and topology. Folding entered architectural discourse

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[31] A short introduction on how complexity is understood here is to be found in Greg Lynn's article "*Blobs"*. (Lynn, 1995)

simultaneously with the spline.[32] I will not dwell on this theme except to mention that the folded surface became the archetypal geometry of continuity in architecture. In practice it opened a new way of spatial thinking. A continuous but articulated surface can host events that are distinct yet connected and related. In many of the realized examples the folded surface has become more a formalistic feature than performative geometry.[33] The questions of formalism related to the architecture of folding are elaborated by Sanford Kwinter (Kwinter, 1997). He argues for a revision of formalism where he distinguishes between a type of formalism concerned with the superficial and the surface form. His arguments highlight the importance of form in relation to event or program. The architecture of folding is literally an architecture of the surface, the superficial and form (formalism).

The other issue of importance is the interest for topology following the continuous surface.[34] Topological deformation means to deform a shape without changing its global features and relations. Structurally, the geometry stays unchanged but the positions and proportions of parts of the geometry are altered. A topological change is easy to program because it does not confront geometric inconsistencies. This is clearly demonstrated in morphing software. If we want to morph two 3D-geometries in a program this requires topological consistency between both samples. It is not possible to morph a cube describing a closed space with a singular open spline surface.

The interesting thing about both folding and topological change is how well these themes fit CAD technology especially the spline. Surface-deformation is easy to do in a spline-based surface modeller. Combined with animation software we have a very easy to use, hands-on digital tool for generative deformation which does not require mathematical or programming skills. It is ideal for the creative computer user in architecture and design.

The theories and the technology are so intertwined that it is impossible to say what triggered what. The tools of the straight lined geometries (rulers, rule-based cad libraries) are ideal for "normal" architecture to a degree that makes it impossible to distinguish the cross influences. How can we distinguish the influence of the guiding principles and the appropriate tool? The same is true of the 'new' architecture of the undulating surface.

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[32] Folding in Architecture has been inspired by Gilles Deleuze (Deleuze, 1993) and elaborated by people like Eisenman (Eisenman, 1993) Kipnis (Eisenman, 1993) Lynn (Lynn, 1993) and Cache (Cache, 1995a)
[33] An example where folding is an important performative geometric feature of the building is Ben van Berkels Möbius House. (Emmer, 2004)
[34] Topology was mathematically described by Pointcare.

Seen from an operational perspective, applying these theories has been successful in renewing architectural thinking, which has resulted in the production of new architectural form. Also digital technology and graphical interfaces have contributed to the further development of visualisation of information and diagrammatic thinking. For designers, an approach inspired by diagrammatic visualisation contributes to develop design computing beyond figurative representation, which is a great strategy to activate the potential of creative computer use in design. This is a central aspect we are going to investigate.

Trends and philosophies in architecture will change, but this period has opened up some principles and possibilities of working with technology. Some of these aspects will survive independent of their ideological bases.

2.3.2. "The suffering of diagrams"

In his essay 'The suffering of diagrams' William Braham states that the dynamic diagram has been adopted by the neo-avant-garde but neglected by mainstream practice. (Braham, 2000) He points to several reasons, some of which are very mundane, such as the lack of time and resources to conduct research-based design processes in commercial practices or the endurance of building typology as the dominant model for architectural working methods. Another schism is the expectation of methods in general and in digitally-aided methods especially the expectation that they would make the design process easier, while the diagrammatic methods of the neo-avant-garde promise the opposite by…

> …intensifying the interpretive demands on the architect by connecting the building-as-diagram to ever more complex conditions and requirements. (p.11)

Braham ends by pointing to a major problem of diagrammatic methods:

> A wholly organic, flexible and adaptive method ignores the desiring (meaning suffering) subject at its peril. Diagrammatic methods succeed precisely where they relinquish their stronger aspirations, situating the humbled architect (post-post-modern) as just another variable in the diagramming. Neither the question of desire nor that of suffering can be lightly dismissed – nor can their place in contemporary design processes. (p.11)

These statements from Braham reinforce the need to investigate the role of the subject (individual designer) in the diagrammatic or emergent design process. What is a possible more engaged role? How are the *intensified*

interpretive demands on the architect balanced with the need for an emotionally engaging design method?

My response to these questions is to reject a totally inflexible and rigid approach to emergent design and dynamic diagramming. There is still a role for the individual designer and this role is important. This thesis seeks to investigate the relation and balance between the subject and the dynamic diagram of the digital machine.

The generative dynamic diagrams described in this thesis serve as devices to negotiate between the parametric machine and the intuition of the designer. The dynamic diagram is no longer (has never been?) a rigid machine but an intuitive device.

2.3.3. Architectural theory and design methodology

Design research in architecture and design research in industrial design represent two different research traditions. Architectural theory and thinking is manifold. It spans from building technology, social building, and sustainable building to theory related to philosophy. The most central, significant and interesting contributions regarding the context of this thesis come from contemporary digital architecture. This was initially inspired by people and offices such as Peter Eisenman[35], UN Studio[36], Greg Lynn[37] Bernhard Cache[38] and many more, later the works and teaching of Michael Hensel and his collaborators, Achim Menges, Ludo Grotemann and Michael Weinstock at the Architectural Association School of Architecture.[39] The most important source of inspiration for the development of theories has been my involvement in OCEAN NORTH initially including Johan Bettum, Kim Baumann Larsen and today Kivi and Tuuli Sotamaa, Michael Hensel and Achim Menges.[40] It also includes a growing milieu of young designers as represented in the entries to the FEIDAD[41] award (Liu, 2002) and in the work of some of my students.

The discourse in architecture includes themes introduced both by philosophy, modern natural sciences and the impact of technology in general and especially information technology. It includes the concepts of the surface as a

[35] (Eisenman, 1993, Eisenman, 1999b, Eisenman, 1999a)
[36] (Berkel, 1994, Berkel and Bos, 1997, Berkel and Bos, 1999)
[37] (Lynn, 1993, Lynn, 1998a),
[38] (Cache, 1995b, Cache, 1995a, Cache, 2004)
[39] See especially the AD issue *Emergence: Morphogenetic Design Strategies* which was edited by the Emergent Technology Group.(Hensel et al., 2004b)
[40] Including a long list of project co-operators. See www.ocean-north.net
[41] www.feidad.org

diagram of continuity and folding, concepts of the information surface or hyper surface (AD issues Hypersurface I and II). It includes a discussion of formalism (Kwinter, 1997) and of a new approach to dynamic systems (Hensel and Sotamaa, 2002).

Other central names and references which have directly or indirectly influenced the work and text I present in this thesis include: Stan Allan[42], Manuel Delanda[43] Gilles Deleuze and Félix Guattari[44], Jeffrey Kipnis[45] and R.E. Somol[46]. These sources have been crucial but also limiting, since I in the later stage of this thesis have wanted to break away from this platform to look at the work from the perspective of the practitioner.

Design methodologies

The beginning of design methodology is normally set to 1962 with the first conference on design methods in London. This marked the start of the design methods movement (Cross, 1984)

The Swedish design researcher Gedenryd suggests a different perspective. He claims that the roots of design methodology are already found in the works of Pappus in Alexandria AD 300. Pappus describes the *Analyomenos,* which may be translated as "the Treasure of Analysis" (Gedenryd, 1998) p 27

With the *Analymenos* Pappus arranges the linearity of causal reason and separates it into two stages, one of analysis and one of synthesis. As Gedenryd points out, all major elements of design methodology are already present in Pappus' *Analymenos*. Gedenryd summarises these elements in four unifying principles:

1 Separation of the design process into distinct phases
2 Arrangement of the phases in logical order.
3 Planning of the activities within a phase.
4 Product-project symmetry. The plan of the process reflects the subcomponents in the design product.

Gedenryd shows how the antique idea of the art of analysis via Polya and Descartes configures the basic principles and sources for the methods of the 1960´s.

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[42] (Allen, 1997) (Allen, 1999a, Allen, 1999b)
[43] (DeLanda, 1999, DeLanda, 2004)
[44] (Deleuze, 1993, Guattari, 1992, Guattari, 1995)
[45] (Kipnis, , Kipnis, 1993)
[46] (Somol, 1998, Somol, 1999)

According to Gedenryd, the classical model of analysis is fundamentally wrong since it confuses process and product. The separation of analysis and synthesis is artificial. The path of sequences described already by Pappus and later by all design methodology is a false idea. Such a segmented path is never followed, but the designer as well as mathematician jumps back and forth between investigation, problem definition and tentative and iterative solutions.

However, Nigel Cross emphasises the value of the second generation of design methodology in the 1970s and 1980s. He points to the fact that it has developed strongly in engineering and some branches of industrial design (Cross, 1984). Also within software-design methodology, this is very much debated, but it seems that the linear "Water Fall" models have recently been replaced by more direct ways of programming where the programmer's skills are more central. The complex logistics of a whole project, where methodology had a central role, must take into account the needs of the individual programmer, and it is acknowledged that programming is an individual process. Methodology is important in programming as it may become again in design. A future debate on design methodology will presumably be less concerned about universal models and possibly more explorative and suggestive. This thesis may be a contribution to this debate.

While the general rejection of a universal design methodology has led to an increased interest in the continuous invention of the process in architecture, this has now also started to influence design thinking. (Broadbent, 2003)

Donald Schön suggests research methods to externalise this tacit way of working (Schön, 1982). Through protocol analysis and *reflection in action* it would be possible to document and systematise tacit knowledge in creative practices.

Lois Pereira (Pereira, 2000) and P.Lloyd (Lloyd, 1995) criticise the research method suggested by Schön. Pereira points to three serious problems with protocol analysis and reflection in action:

1. Reflection in action distracts design thinking. It does not take in account the distracted and detached techniques. Many designers are often in tentative intuitive phases where they do not exactly know what they are doing. The value of these open-ended ways of working is becoming more accepted. (ed. Atkinson and Claxton, 1999) The very point is exactly to avoid the type of conscious control induced by reflection in action.

2. Protocol analysis is impractical for covering the complete design process. Reflection in action does not cover the activities that take place in the meeting rooms, on the subway, in the shower, in interaction with other professions involved in the process or in the synergy between practice and theory.

3. Protocol analysis puts emphasis on verbal processes on the cost of visual processes. Visual thinking is closely connected to verbalisation but the point is that in protocol analysis the visual material is thought of as being secondary instead of primary to visual thinking.

Protocol analysis is valuable as long as we are aware of the problems involved. In some cases notes written retrospectively are more operational because they analyse a recent practice without disturbing the tentative and intuitive elements of the process.

Design methods as suggested by the design methodology movement might have failed, but at least they analysed ways of thinking and working as designers. In the future, we may return to many of the ideas from that period and use them in a more flexible way. A suggested new position for design methodology would be to detach methodology from both a descriptive intention and a normative universal intention. If we recognise the design process as a largely cultural invention, the task for design methodology is to modify it, develop it and reinvent it. This means not abandoning the methods but widening the scope and letting creativity and exploration enter design methodology.

In architecture we can find such an approach.[47] There is a great interest in the process and new methods and processes constantly developed. Process orientation does not necessarily imply the formalisation of a methodology. To the contrary it implies the ongoing invention of the process.

2.4. IDEAS ON CREATIVITY

Creativity is a phenomenon that we can modify despite the continued uncertainty about what really defines creativity. I will argue that we can bypass the current discussions about creativity research and base our conception on the operational creativity of the creative professions. This creativity is to a great extent a cultural phenomenon. The creative process is an invention which includes the tricks and methods for creative work

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[47] This is apparent in Architectural Design were several issues are about the digital process.

developed by the relevant profession. This insight will make it plausible to reinvent the creative process.

Inspired by the diverse models of creativity found in cognitive research, I will bring forward a view on creativity that is less based on the internal potentials of the individual mind but more on the ability to be inspired by external impulses (finding).

I will emphasise the heuristic aspect rather than the algorithmic as important in the development of digital creativity.

These are summarised in a proposal for a practitioner approach to creativity which voices the tacit knowledge of the creative professions.

2.4.1. What is creativity?

Despite considerable efforts and achievements in research on creativity the cognitive aspects of creative processes still appear to be fuzzy and hard to understand. Richard E. Mayer describes the situation in creativity research within psychology as *"...seemingly chaotic diversity"*. (Mayer, 1999) Even to define or reach a consensus on what creativity really is seems to be difficult. This has been an obstacle for creativity research. Amabile demonstrates that the lack of consensus on a universal definition of creativity does not mean that it is impossible to investigate creativity in a scientific manner. (Amabile, 1996) She puts forward an operational definition of creativity, tempting to establish a basis from which the phenomena can be researched. This definition is twofold:

> A product or process is regarded as creative if judged so by appropriate observers.

To frame the criteria for judgement, Amabile adds a conceptual definition:

> A product or response will be judged as creative to the extent that (a) it is both a novel and appropriate, useful, correct or valuable response to the task at hand and (b) the task is heuristic rather than algorithmic. (Amabile, 1996) : 35)

In the entry on heuristic method in the Fontana Dictionary of Modern Thought we find the following definition:

> A procedure for searching out an **unknown** goal by incremental exploration, according to some guiding principle which reduces the amount of searching required (Bullock et al., 1988).

Heuristic processes are most central in design practices and also find a natural application in design research.

Most definitions of creativity involve novelty and value. What novelty and value implies is conceived in various ways. Mayer asks rightfully if novelty and value are features of people, products or processes. All three principally different views are represented within creativity research. The question of judgment by appropriate observers and the judgment of value open a wide range of possible answers. Who is appropriate to judge what value? The creativity researchers solve these problems by contextualising and exemplifying the cases and the description of what we are talking about.

These operational definitions are based on the visible outcome of creativity rather than attempting to describe creativity as a phenomenon. Although the definitions are imperfect, there exist a number of descriptions of creativity. Recent studies regard creativity to be a conglomerate of various phenomena. Creativity is not a singular principle but a field where we can find several different theories.[48]

Mayer outlines a series of important unsolved questions in psychological research on creativity, questions that present the different views within creativity research. One concept the different positions seem to have in common is that creativity had to include both elements of originality and usefulness. How originality and usefulness are understood and defined varies between the different positions. Novelty and usefulness in a painting is clearly different from that in a technological component. In complex products we can find many different expressions of novelty or usefulness, which can be judged completely differently depending on the "value-perspective". This leads directly to Mayer's questions:

Is creativity domain-general or domain-specific?
Is creativity a property of people, product or process?
Is creativity a personal or a social phenomenon?
Is creativity common or rare?
Is creativity quantitative or qualitative?

A productive and pragmatic approach to all these questions seems to be that creativity is a complex conglomerate of processes, activities and properties. Creativity appears both on an individual level and as a social activity. Creativity in one form or another seems to be common to all humans, but at the same time it seems to be rare in its most significant form. Certain aspects

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[48] For references see (Sternberg and Lubart, 1999) "Confluence approaches to the study of creativity" (Amabile, 1996, Csikszentmihalyi, 1996, Csikszentmihalyi, 1999, Gruber, 1988, Sternberg and Lubart, 1995).

of creativity can be measured with quantitative methods, while others are of a qualitative nature. All the different approaches are reasonable explanations of parts of the phenomenon.

This indicates that we need to describe what aspect of the creative process we are talking about. It further leads to a dynamic view on creativity as a cultural phenomenon that is open for change. It puts the designer back in the driving seat and enables the invention and refinement of new creative processes.

2.4.2. Creativity, a cultural phenomenon.

Creativity is regarded as a kind of natural phenomena that we can research and try to understand and thereby improve performance. But the possibility to alter this phenomenon has seldom been investigated. We can train this feature of the human mind just as we can train our legs to run faster (Stein, 1975) but we cannot alter its fundamental features.

In contrast to this conception we can look at creativity as a culturally conditioned phenomenon. If this is true, creativity and our conception of it are likely to change according to cultural changes. To investigate this further we can look at the historical development of how creativity has been understood through the ages.

Historically, creativity was thought of as an external divine force. (Csikszentmihalyi, 1996) The individual, inventive type of creativity celebrated in the industrial society seems to have been totally absent in ancient cultures. Artistic creativity was understood as the ability to imitate (Sheppard, 1987).

Plato regarded the highest level of art as imitation (mimesis). Every entity in the world had an ideal divine form. He regarded the elements of the physical world to be lesser ideal copies of the abstract ideals. A piece of art was regarded as even more distant from the ideal since it normally was an imperfect imitation of the less ideal real-life form. Still art should try to imitate the ideal form of the real-life object rather than its physical representation. We can find similar ideas about creation in Asian cultures (Albert and Runco, 1999). Plato still regarded the creative process as something special, since he argued that an artist was only able to create when a Muse dictates (Sternberg and Lubart, 1999). External divine spirits inspired the genius mind. Originality became a feature of creativity much later. The task of human creativity was to reproduce the divine ideals.

After the Renaissance this view was gradually replaced with the view that there was a creative force inside the human mind, and that the genius was a specially equipped individual. The invention of scientific research, industrial

production and the enlightenment were important contributions to the modern view on creativity. The idea that the human being was able to dominate nature and modify it according to human will was a basis for individualism. In the eighteenth century the long debates about individual creativity settled in four distinctions (as formulated by Albert and Runco 1999):

- Genius was divorced from the supernatural.
- Genius, although exceptional was a potential in every individual.
- Talent and genius were to be distinguished from one another.
- Their potential and exercise depend on the political atmosphere at the time.

Another important aspect in the contemporary understanding of creativity stems from the Romantic Period in the seventeenth century (Sternberg, 1999) (Abrams, 1953). Art became an expression of spontaneous emotions. The belief that emotions are the source of artistic creativity has dominated art in the last 200 years (Sheppard, 1987). This belief is still widespread despite the fact that it has been challenged by many eminent artists.[49] Freudianism reinforced this interest in individual emotions and contributed to turning art into an investigation of the subconscious. Psychodynamic models regarded creativity to be a product of the tension between the conscious and the unconscious (Sternberg and Lubart, 1999). The emphasis on spontaneity and intuition in creative processes can be traced back to this view. These perspectives are products of modern society and its focus on individualism, and can not necessarily be regarded as universal

Any creative individual is influenced and dependent on context. This context can be described on a macro level, the contemporary conditions in society (e.g. Leonardo Da Vinci as the universal genius in the Renaissance) or on a micro level, the individual relations and connections and specific access to information the creative individual is exposed to (Stillinger, 1991). [50] With the dramatic shifts in society caused by information technology the focus has moved from individual creativity to communication-based creativity. Jack Stillinger attacks the myth of the solitary genius. (Stillinger, 1991) Michael Schrage emphasises the importance of a shared space in which to pool ideas. (Ref: Michael Schrage at Ultima 99) In the age of communication technology isolation is no longer a strong ideal for the artist.

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[49] Artists like Andy Warhol who equals painting to an industrial process, Jackson Pollack who lets chance play an important role and Picasso who emphasises a process of finding which indicates an external source of inspiration.

[50] Context is important even to artists who in periods were isolated like Gauguin or Cezanne. Their isolation could be seen a result of the ideal of their time, the isolated genius.

The use of information technology opens up new possibilities to improve collaboration and play down individual creativity and authorship.

Such a system has been used at ETH[51] where a large group of architectural students collaborate through leaving individual designs on a common database for others to pick up and work on further (Engeli, 2001). In this system, what is most interesting is not so much the collaboration as the tracing of individual authorship. This opens up a new mode of creativity made possible through information technology. All files are accessible to all others but they also keep a record of their creator and the history of who and how they were updated (Schmitt, 1999).[52]

Stillinger shows through several case studies the complex mechanisms that influence the creative process, in this case writing and publishing a novel. But he goes further and claims that the process of distribution alters the content. The medium is the message since it continuously alters and modifies the appearance of its content (McLuhan, 1964). The increasing complexity and quantity of accumulated human knowledge makes it ever more impossible for the myth of the solitary genius to survive. Stillinger demonstrates how technology alters the conception of the creative process. The fact that knowledge accumulates through communication is recognised in recent research approaches to complex problems through different methods such as the Delphi Method (Linstone and Turoff, 1975). Also in a educational context, the advantages of "communication based creativity" (social creativity) are being recognised and this has resulted in more joint projects, shared authorship and group activities such as colloquium groups.

In today's information society we can recognise similar concepts. The model of the individual universal creative genius, a Renaissance idea, is long thought of being impossible since the amount of accumulated knowledge has bypassed the capacities of the singular human brain (Stein, 1975). Today the idea of singular authorship is questioned and challenged by a growing understanding of the importance of cultural and social context and the flow of information, which leads to increased sharing of information, knowledge and ideas (Stillinger, 1991). Information technology accelerates the exchange and therefore the continuous reconfiguration of information. Clearly these powerful mechanisms cannot be ignored in the long-term when it comes to our cultural understanding of the sources of creativity.

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[51] Swiss Federal Institute of Technology Zurich, Department of Architecture.
[52] Similar ideology lies behind the international collaboration of OCEAN NORTH and some other networks in architectural design.

While the myth of the solitary genius was the product of modern thought, the information society slowly replaces that myth with another one, the myth of the creativity of sampling. Sampling was early an experimental technique in electronic music (Barrett, 2004). In popular music of the 1990s sampling was applied in a large scale and became a major feature of mass culture. Parts of soundtracks were relocated, creating unexpected juxtapositions. I interpret this as an expression of post-modernity. The post-modern was not innovative in the sense of continuously searching for novelty in striving to push modern culture forward. On the contrary, it opposed the idea of modernity and from that it follows that creativity under post-modernism was about the re-conceptualisation of references to the past.

In product design and architecture, professionals face ever-increasing complexity in their projects. The amount of information and number of actors in the building process or in the process of bringing a new product all the way from concept to the market are overwhelming. This difficult situation requires some reconfiguration of how architects and designers work. On the one hand we need to develop techniques to apply creativity to design in complex situations. On the other hand we need to share authorship. Product design and architectural design is, to an increasing degree, regarded as teamwork rather than the outcome of one single master architect.

However, the creative individual is important and might even increase in importance in the future. The question is how we understand individual creativity. Feldman, Csitzentmihaly and Gardner suggest treating the creative individual as part of a system with three levels:

- The field
- The domain
- The person

(Feldman et al., 1994, Gruber and Wallace, 1999)

The *field* represents the area of competence, the art or the profession. The *domain* represents the closer working milieu, in other words, the environment where the individual can have a direct impact. In addition to personal creativity, the results are largely influenced by the state of the field, if it is a field that is under development and where innovation and originality is sought after, and by the domain, if the person is surrounded by a supportive and challenging environment.[53]

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[53] A colleague of mine Maziar Raein mentioned two important factors that would contribute to the forming of a domain were creative processes can thrive: The domain has to be an ambitious and competitive environment, but equal important is that there has to be a large degree of generosity.

2.4.3. Creativity in the information age

From the Renaissance up to the Enlightenment, the industrial society and finally consumer society, the main concept of creativity was based on the notion of the genius where the individual was regarded more important than context. It is natural that the information society with its increased connectedness and simultaneous access to information and communication of knowledge and ideas moves attention to the context (field and domain) of the creative individual. This is manifested in an increasing number of networked creative environments (like OCEAN NORTH) but also communities and groups of designers located together (e.g. Droog)

Connectedness

In the age of Internet, connectedness and communication, cultural changes are obvious. People like Sheryl Turkle (Turkle, 1995) and Rosanne Stone (Stone, 1996) considered the rise of digital cultures as early as in the first half of the 1990s. They pointed to the importance of subcultures in western society as initiators of these cultural changes. Since then digital cultures have become so embedded and familiar in affluent society that it is less easy to see the great changes that have taken place. Remote cooperation, accessibility, the rise of a do-it-yourself culture in new areas and the anarchy of cracked software[54] have had a major influence on what people do on the computer.

In modern urban subcultures, e.g., in the music scene, these technologies have been influential. The attitude towards the creative process has altered. It is now acceptable to steal pieces of music and use them in new contexts. The conception of originality has changed. This new kind of creativity comes less from the individual and more from sharing information. The sharing and accessibility of information which makes reproduction quick and easy has already challenged notions of single authorship, copyright, distribution methods and most of all the ownership and capitalisation of human thought and culture. In the age of information technology, human culture is regarded as a public sphere. As long as you can crack it, it's yours.

Accessibility

Software development has made a wide range of technologies accessible for the connected masses. Digital photography, image processing software, sound mixing and synthesising software, and video editing software are all examples of technology which was only used by specialised professionals. Now software with a professional level of performance is available to anyone

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[54] The cracking of serial numbers has greatly contributed to the spreading of advanced software. Though this is stealing from a legal point of view, many software companies choose not to pursue such crimes because they realise that distribution of their software, by whatever means, is ultimately beneficial to them.

at a reasonable price.[55] Increased accessibility has changed the conditions for creative professionals. It breaks down the barriers between design professions and produces more flexible and interdisciplinary designers. The creative process has spread to the masses while it has become more diverse for the professionals.

Reuse and evolutionary design

Reusing means to use elements developed in one design process in a later design process.

Another possible outcome of design in the information society is increased attention to innovation as evolution. Since it is relatively easy to access all kinds of background information regarding a design project it is also easier to relate to existing solutions and develop these further.[56] Files from former projects are easily re-used. Component libraries are of great help. This might change creativity into a process that is only artificially broken up into phases because of customer demands, but which from the designer's perspective, is continuous because you might start every new project with some digital material from an earlier one.

Sampling

Sampling techniques in modern music is a good example of such new conceptions of creativity where elements are reused. Bits of music are replaced and removed from their historical context and reassembled into new unexpected situations.[57] The icon of this new attitude to originality and creativity is the DJ. The DJ is acknowledged for the selection and assembling of music and less for composing in the traditional sense. Accessibility and connectedness has created impulses independent from established art and design education. This is a new generation of artists and designers who seem less introvert, lighter, quicker, more responsive and adaptive to the ever-changing patterns of the information society. A large part of this generation has learned its skills not in traditional art and design schools but through communication and sharing of samples.
(More about sampling is found e.g. in Manovich (Manovich, 2001)

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[55] Examples to be found in price dumping of 3D-modelling software like Alias or in video editing e.g. software like Adobe Premiere reaching a professional level at a fraction of the price of the competition.

[56] The Product data management systems provided by most high end CAD systems are concerned about sharing project information and reusing components stored in accessible databases.

[57] This is actually very similar to one of the creative models suggested by Pointcaré (Martindale, 1999).
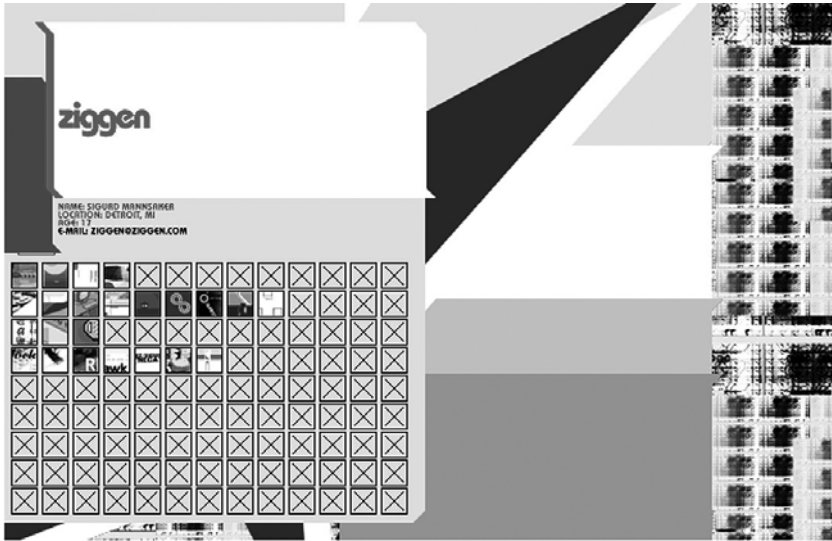
Figure 18 The talented young autodidact designer Sigurd Mannsåker is a very good representative of the new generation of designers without a traditional arts and crafts training. (www.ziggen.com))

2.4.4. Creativity-enhancing techniques

Within diverse professions the problem of creativity has been treated from a practical pragmatic point of view. The main research topic and interest is in the development of techniques and methods that help any practitioner to become more creative, hence more productive. We find this kind of research, often in a popularised form in diverse professions, but most articulated in business related areas. Osborn developed the technique of brainstorming, based on his experience from advertising. (Sternberg and Lubart, 1999) (Osborn, 1953) See also (DeBono, 1992, Oech, 1986, Stein, 1975). Although many creativity-enhancing techniques have been suggested, the only one that seems to have been generally adopted is brainstorming. According to Csikszentmihalyi, such techniques are variations of 'divergent thinking'. Most programs for enhancing creativity are focused on the production of ideas. Csikszentmihalyi points to three general features of such techniques, *fluency*, *flexibility* and *originality*. Fluency means to produce a great number of ideas, flexibility to produce ideas different from each other. (Csikszentmihalyi, 1996)

A problem with these techniques for creative people who work with visual art or design is that the techniques are focused on verbalisation more than visualisation.

Divergent thinking techniques are useful when it comes to challenging our preconceptions. But their weakness is that they are based on semantics rather than visual thinking, which limits their usefulness for visual work. These techniques are therefore less important for the type of creative work we are looking at here. In this work the visual is central and reasoning is based on and supported by visualisation.

2.4.5. Crucial micro-cultures

I use the term micro-culture as a more specific term for domain. It emphasises the social, ideological and cultural aspects of the domain, which I regard as especially important in the fields of cultural production.

Recent creativity research suggests that one of the most efficient things to do to enhance creativity is to alter the context rather than focus on the individual level. As already mentioned, there are at least three levels on which we can consider creativity: the individuals the domains and the fields (Csikszentmihalyi, 1996, Csikszentmihalyi, 1999, Feldman, 1999). One such context on the field level is the historical context. All important discoveries are based on the achievements of predecessors and the general contemporary conditions in society. Csikszentmihalyi compares Einstein's creation of the relativity theory as the spark that lit the fire, but without oxygen and tinder the fire would not ignite (Csikszentmihalyi, 1996).

The most substantial investigation of the influence of social factors on creativity has been conducted by D.K. Simonton in an investigation of ten very eminent musical composers. (Amabile, 1996) But creativity also operates on an everyday level, a more spontaneous ad hoc sort of creativity, which seeks to solve whatever problem is faced. For design professions both types of creativity are of importance. The historical context is not something we choose or are able to alter.

But the domain context is possible to change and influence. We can associate with people who share the same ideas and attitudes and who respect each other and who are able to create an atmosphere where fear of failure is reduced. The brain-storming rule that forbids negative responses is a good example of instantly altering domain-conditions in a way that nurtures creativity. It is beyond doubt that the qualities of the social and physical environment are of great importance for creative work. We are in a position to at least partly control, alter or even create these conditions. Co-operation between people with shared perspectives and enthusiasm can produce results which would otherwise not be possible.[58]

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[58] OCEAN NORTH has been such a context for this thesis.

2.4.6. A proposal for a practitioner approach to creativity

Creative practitioners have a deep knowledge of creativity. Often this is a tacit knowledge. Practitioners often have a humble attitude when talking about creativity. They could gain from both voicing their experience and experimenting with their conceptions of creativity.

In this thesis I assume that at least some aspects of the mental and social processes that are involved in visual creative work are changeable. We can alter these processes through practice. This means shifting our focus from the investigation of conceptual processes and techniques towards the study of practice. The focus is on research and development of creative techniques based on visual representations aided by computer technology. Also the micro-cultures or the domain of the designer are important. It is crucial for the individual's creativity that his or her domain develops culturally in the sense of a common knowledge base, attitude and forms of expression that are constantly thriving and being renewed. The expression of ideas and ideologies and the exchange of positions are important expressions of this state of culturally conditioned creativity.

When we move the focus from the internal aspects of creativity to the external aspects, the problems are also externalised and we can concentrate on the core of the design profession. Research moves from the descriptive towards the exploratory. The core of design research can be seen as a design activity. This research / design activities´ goal is to develop adequate design knowledge (Dilnot, 1999). The theoretical base relates to pragmatism (Dewey and Bentley, 1949)

The practice-oriented approach to creativity is frequently criticised by cognitive psychologists. (Sternberg and Lubart, 1999). Sternberg criticises the commercialisation of creativity research and the lack of theory and validation. Though this criticism is relevant, the study of creativity should not be limited to cognitive psychology alone. Especially studies within the "creative professions" should have a potential to contribute with useful knowledge for creative practices. The study of design techniques must be regarded as research on creativity from an insider perspective, while the psychologists' study of creativity is based on an outsider perspective. The development of design techniques can only be done through research from within the creative professions. It involves first-person knowledge about design practice. Rather than looking at such profession-based inquiries as roadblocks (Sternberg and Lubart, 1999) psychologists should welcome them as useful supplements.[59]

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[59] See also the examination of 100 doctoral thesis on creativity by Wehner, Csikszentmihaly and Magyari-Beck (Wehner et al., 1991)(Also the psychological studies of creativity tend to focus on the exceptional genius as the utmost prototype of

The empirical base for such research would be the development, testing and practice of techniques and reporting of results and experiences. Generalisation would be achieved when other designers try out, adapt and develop further the suggested techniques.

2.5. SUMMARY AND CONCLUSION OF PART 2

We can distinguish several areas or concepts where the use of computers in the design process has been investigated.

1. The development of easy to use and "intuitive" software and user interfaces which promise to make the design process easier and faster.
2. Research on artificial intelligence and the development of agents and expert systems.
3. The development of self-configuring artefacts, genetic algorithms and similar techniques.
4. The development of a family of concepts called dynamic diagrams that are intended to do the opposite of the three above, namely to intensify the design process to make it able to engage in the increasingly complex systems of our contemporary society.
5. Generative Dynamic Diagrams that are intended to operate as devices for the designer to engage with the parametric driven models of the dynamic diagram.

In electronic art and "multimedia architecture", we can find the most radical use of technology, but these areas seldom address the question of methodology. They do, however, address the question of 'effect' and relevant techniques for the production of effects, and hence they are method oriented. But these radical methods and approaches have not yet migrated to a significant degree into the area of object design.

We have to adapt to technology to take advantage of its potential. Every new technological achievement changes the way we live and the way we conceive ourselves. Current dramatic changes do have a major impact on our culture. Our design methods and ways of carrying out creative work are no exception.

The alteration of our ways of working is grounded in a redefinition of design methodology as a flexible suggestive normative activity.

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the creative mind, or on the contrary, on paper-and- pencil tests of ordinary average populations. (Psychometric approaches) (Sternberg and Lubart, 1999)

The focus on our relation to the potentials in the technology contributes to the further development of these techniques away from a (false) belief about their autonomy and towards a defence of the subject, the designer as the major driving force in these processes. Working in a generative way implies shifting the design activities and emphasis from singular products to process design and ranges of design output definitions. This shift seemingly reduces the direct involvement of the designer with the singular design process, but the generative process actually demands a new type of sensibility. It demands awareness of the process and a subjective ability to forecast the potential of the process and its output.

Finally, I suggest raising a pragmatic view of creativity based on the practitioner's experience in order to instigate a state where this can become a concept for operation.

3. New design techniques

This part discusses themes that are central to creative computer use. Here we look at themes like emergence, the virtual, visual thinking and creativity. Finally I develop the discussion around the generative diagram as an over-branching concept for creative computer use.

3.1. INTRODUCTION

Digital technology offers new possibilities regarding the way we work in creative design processes. Until recently the computer served as an aid to speed up and rationalise the workflow, reduce errors or to monitor logistics. Alternative creative strategies and methods adapted to existing computer technology are now rapidly emerging in experimental design[60]. This happens mostly amongst staff and students at certain architectural schools, but also an increasing number of the new generation of designers have started to introduce the techniques in real-life practice.[61] In many such cases the computer is used as a machine to support and run generative design processes. The arguments for doing this are many and diverse, but from a perspective of design methodology, such generative processes are meant to produce unanticipated output[62] that can fertilise the design process. The use of generative material raises many questions about the design process and about the role of the designer.

Despite the fact that there are many diverse theories about creativity, most of them include the emergence of the unanticipated as a central element. At the beginning, the end is not in view. This is embedded in our conception of the design process as a mode of creation. Creation implies a process through which we arrive at something new which has not been envisaged before.

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[60] They do still not spread into "normal" design practices, as mentioned in part 1.

[61] see Peter Zellner, Peter Eisenman(Eisenman, 1999a) Greg Lynn (Lynn, 1999), See ANY 23 for a collection of essays.

[62] Or anticipated and specific output-ranges of individuals that are not anticipatable in their precise articulation.

If we could leave creativity entirely to the computer[63], there would be at least two negative impacts. Firstly, the designer would be reduced to a less creative workhorse in the design process. This would probably take away the most central motivation for being a designer. Secondly, the results would be unprocessed formalism with no cultural content or meaning, since culture in human interpretation is meaningless for machines[64]. The ways of thinking and the techniques suggested here indicate a slightly altered but not alien role for the designer. The designer is still in charge of the process but engages in a play about control with the technology. The focus is moved from product towards processes that will produce ranges of possible output. Creativity is now regarded as the inspiration from the shifting interaction with a slightly uncontrolled machine that is made to produce the unanticipated.

3.2. NEW TECHNOLOGY - NEW STRATEGY

In a relatively early study based on a survey of his students, Colin Beardon concludes that many designers are *contrary users of software*. (Beardon et al., 1997) They often claim that they only get interesting results when they get an error, or something goes wrong. This may sound like a rather farfetched assumption. Mostly errors do not produce interesting results. What Beardon's students are talking about are the few errors when the software produces a graphical output that has a certain visual quality and which is interesting because it is unanticipated (emergent). Beardon's survey can be seen as a comment to the new attitude that is taking form amongst the new generation of designers. When facing problems they apply "walk-around strategies" rather than forcing the technology to produce an exact output of their vision. The process slowly changes towards a higher degree of opportunism, responsiveness and interaction with the media. During a flexible design process, both the concepts (thinking) and form (practice) undergo considerable change and development and the initial intentions or starting points may be totally lost. The emphasis and acceptance of a less controllable and more heuristic design process powered by electronic media has introduced a new awareness of these aspects.

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[63] Genetic algorithm and artificial design intelligence.
[64] Greg Lynn says that .. *the failure of artificial intelligence suggest a need to develop a systematic human intuition about the connective medium rather than attempting to build criticality into the machine.* (Lynn, 1999)

3.3. THINKING THROUGH DESIGN PRACTICE: THE INSPIRATIONAL PLAYFUL DESIGN APPROACH

As designers working with electronic tools, we are more likely to accept loss of control, because we experience the advantage of playing around with the technology. Loss of control implies that we are looking for inspiration in the material we are able to produce. Finding inspiration in external material rather than in the internalised cognitive processes is not a new thing, but for many designers this is not entirely acceptable. Some argue that originality is a talent inherent to the designer, while others argue that there is no real originality, all design is redesign (Michl, 2002). Keeping in mind the diverse models of creativity (see part 2) it is of course possible to find validation for both positions. I prefer to look at these issues as gradients of influences rather than as contradictions. With this perspective, we can in our design work ambulate between internalised creativity and creative work that is inspired by external input.

The argument of redesign implies that we as designers receive our main inspiration externally, from the work of other designers or our own earlier projects. There is nothing wrong with this. On the contrary, this is a valuable working process that is based on the cultivation of tacit knowledge, explicit experience and skills developed within a profession over years. If we replace some of these "profession-internal" sources of inspiration with impulses from other fields, such as art, music, nature or social life, we should be able to achieve some slightly more original results. Seeking inspiration further afield than in the safe havens of our profession is of course more demanding and it involves an additional process of translating and interpreting the material. But it is this way of working which opens up the computer as such a powerful creative tool when we seek inspiration in the emergent output of the machine.

When seeking inspiration in other fields, one depends on a playful and open mind and the ability to assimilate material that is not obviously useful at first glance. The process involves numerous experiments that produce computer-generated material in all possible forms and subsequent exploration and investigation through altering the material and techniques of recoding, translation and interpretation. A designer with a great repertoire of computer skills and experience will be able to play these games in a very efficient way that produces a great deal of material from which the designer will be able to choose. The playful designer accepts creativity as a complex process of diverse influences, and he plays along with computer technology more than struggling to achieve control, although both attitudes can be found (and are needed).

3.4. A CORNER STONE: EMERGENCE

What is emergence?

It is not easy to answer this because the term is used in so many different ways. In everyday language it simply means to appear or to become (visible) (Cowie, 1989). A simple inclusive definition would be: the appearance of a novelty that is not obviously predictable or foreseeable. (Bullock et al., 1988) A more complex definition is:

> Emergence: synergetic and macroscopic phenomena of dynamical systems explained by collective and nonlinear interactions of their elements. (Floridi, 2003)

Another more elaborate and may be useful definition I found in the online glossary of COSI [65]

> Emergence refers to the appearance of higher-level properties and behaviors of a system that while obviously originating from the collective dynamics of that system's components -are neither to be found in nor are directly deducible from the lower-level properties of that system. Emergent properties are properties of the "whole" that are not possessed by any of the individual parts making up that whole. Individual line of computer code, for example, cannot calculate a spreadsheet; an air molecule is not a tornado; and a neuron is not conscious. Emergent behaviors are typically novel and unanticipated. (COSI, 2000)

Emergence is a term that refers to many different fields, from biology to the social sciences, informatics, system thinking and in the understanding of nature. Emergence as a phenomenon has always been a part of design in practice, but the various concepts of emergence which influence design come from many sources, and the conceptualization of emergence in combination with the potential of new technologies (as well as scientific discoveries / inventions) change the relations that designers have towards emergence in design. One way in which the concept of emergence came into the design realm was by digital designers who were inspired by electronic artists who have been experimenting with generative processes for many years. Recently emergence in design is seen as not only a process supported by digital technology but as a useful design principle in general. (Hensel et al., 2004b) In our case we adopt the same framework as electronic artists who regard emergence as a feature of a process in which generation is supported by machines or processes that are partly out of the artist's control.

In design, emergence is used in several ways:

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[65] COSI (Complexity in Social Science) was a three year EU-financed research project with participants from many EU-countries.

- The use of a source material that dictates some of the conditions of a design process which thereafter follows a path that is less controlled by the designer; the result which eventually emerges from this (digital) process will have an element of novelty and surprise.
- The design of conditions for and according to emergence in urban or natural systems.
- The use of emergence in material systems, how materials self-organise into structures.
- Computer simulated emergence, like self-organising architecture or genetic algorithms, cellular automata or self-organising and self-growing architecture.

Emergence in design computing becomes clarified as a concept through computer technology. Graphic software is driven by a large number of parameters, (see Figure 19). This promotes a process of trial and error and of finding. When we semi-accidentally find a good shader, we store it. But then the lighting sources are different in the next scene and we start to adjust the parameters. Soon we begin to develop entirely new shaders and the process is to a considerable degree driven by accident and finding.

This is not a very alien process, unknown from before computer technology. Trial and error and finding is normal in many crafts. Less obviously, similar trial driven and intuition driven processes exist in water-colour painting. Water-colour painting techniques are especially signified by the slight lack of control. But to find real emergent designers from before the computer age we need to look at modern music.
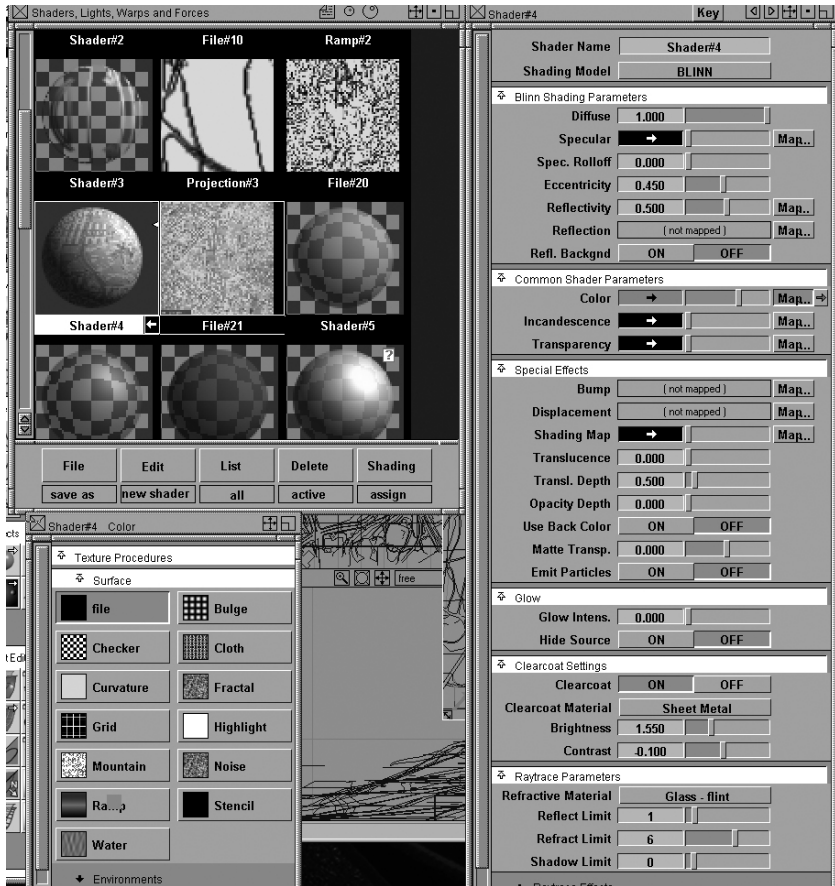
Figure 19 The interface for the creation of shaders in Alias Studio. The possibilities are virtually infinite, which makes it hard to gain any consistent control. The process is forced into trial and error modes and eventually intuitive use. The result has an emergent driven aspect.

Fifty years ago, musical composers were already working along lines that are very similar to what digital designers do today. At that time, composers started to get access to recording machines.[66] Some of them started to experiment with the technology. Recorded sound was cut, rearranged, juxtaposed, modulated and reversed. (*Music Concrète*) The composers often had little idea of what the sound results would be. Important factors were the selection of the sound source for recording and experimentation within the

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[66] The comments regarding emergence in musical composition are largely based on communication with the composer Natasha Barrett (Barrett, 2004)

given framework of the technology. The results could be surprising and sometimes bore no resemblance to either source sound or experimental process. From these results, the composer would then select materials via an aural approach. The basis for selection would normally begin with the completely subjective grounds that 'for some reason' a certain result sounded interesting. Further transformation and permutation would gradually get the developmental ball rolling, but still without the composer having a clear idea of where the development might lead.

Later, the same approaches were developed further by contemporary electro-acoustic composers. The basic principles stayed the same but the introduction of computers changed the conditions in several ways. The experimentation process became much quicker. More material was produced and transformed with far less effort. Transformation became more extreme and the selection of material was altered because much more material could be discarded.

Simple early experiments allowed the composers after a short time to develop an intuition and to anticipate the result. Computers allow the use of complicated processes that can often defy prediction of the result.
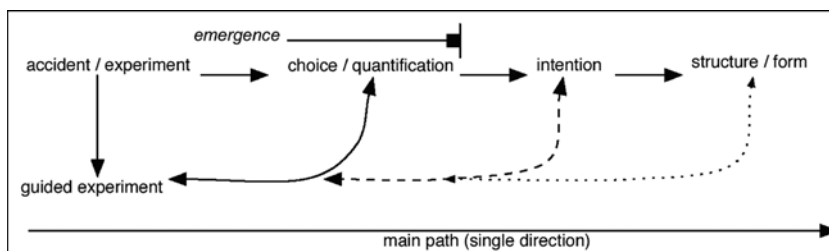
Figure 20 Feedback within discovery strategy. As you move further to the right, the role of 'emergence' and the likelihood of the current stage feeding back into an earlier stage diminishes as the work takes on structure. (Barrett, 2004)

Despite the result being more-or-less unpredictable and the process tending to develop a substantial distance away from its starting point, the source material is of great importance. It can be visual or auditory material or an algorithm, the process and its results would be different:

> In electro-acoustic composition, to allow the unknown to 'emerge', the composer can begin in two ways: selecting acoustic source material as mentioned above, or using sound synthesis algorithms where there is no initial source sound - instead the composer selects only the algorithm, constraints, and time varying parameters (Barrett, 2004).

In visual design, the situation is similar. It is possible to start with an algorithm e.g. a noise pattern in Photoshop or a genetic algorithm and develop it along chosen rules. But it is also possible to start with an initial source material that will produce different results.

The advantage of starting with a visual source material compared to an algorithm comes from the complexity already inherent in the visual or acoustic material. Natasha Barrett puts it this way:

> If you begin with complex source material the results are normally richer, more varied, and therefore provide a denser set of (correlated) information from which the composer can be stimulated. The smallest aspect of a complex result can incite the composer to follow a previously unimagined path. I use the word correlated in brackets because all acoustic sounds apart from white noise contain highly correlated spectral information – that's why we hear quantifiable sound and not randomness (noise). Applying exactly the same process to different sound sources will often lead to extremely different results. We can view this as bringing together two knowns and producing the unimagined.

Similar to sound material, but not so obviously, visual material except white noise is always highly correlated. Barrett also discusses how the learning process will influence emergence in the design process:

> After extended use (years?), the user often begins to learn how the output of a process will sound regardless of the variety in the input. This may be a good thing if the composer approaches development and structure from pre-determined criteria, but it is detrimental to emergence and discovering strategy.

The results from repetitive use of one certain technique over time will encourage preconception of the output and the element of surprise will be replaced by a new level of control. This indicates that the unavoidable gain of control over time has to be re-challenged with new inventions for the process. The hybrid strategy that I will present towards the end of this thesis also contributes to counteracting the development of routines which, over time, erode the practice of emergence.

3.4.1. The source material

We can understand the traditional sketch by hand as the first "seed" or source material for a design. Normally, designers start with other information than the visual. The first initial information could be a text such as a brief of the market, production facilities, and existing products. Similar information for architects would be a room program, site information building laws, budgets and so on. How this early information influences the design process is worth studying for its own sake. For this thesis we will limit the discussion to the role of the first graphical input.

The design strategies suggested here would be more likely to start with an initial graphical input than a traditional process. The type of information mentioned above would actually be inserted somewhere down the road of the design process, when initial organisational possibilities or actualities have been generated on an abstract level.

We frequently use the term *seed* for this first input. The term *seed* is also used in the theory of genetic algorithms. The way we use the term *seed* here is similar but nevertheless different. In genetic algorithms, the *seed* is an algorithm that will initiate an artificial life span. This artificial life form will develop without any interference from external forces through automated feedback loops and processes that simulate mutation. The *seed* in our context is first of all not an algorithm but a piece of graphics or other information. Secondly we do not normally use this as input to an automated process, but as input to a manually controlled though computer-aided process. The difference is that we as designers choose to maintain the freedom to interfere, alter and manipulate the process at any time. We ourselves make the rules and the rules are followed only as long as they make sense. We can find some similarities with genetic algorithms in the fact that both techniques leave certain moments to the computer to produce unimagined and unexpected results (emergence). Lately I have used the term *source material* instead of seed. This term covers our use of the material better than the term seed. [67]

Through what has been said so far, we focus on the structural qualities and the potential complexity of information channels in the initial graphics, while semantics and content are less important. Let us take the full step and state that the initial source material should be purely structural and only render organisational principles (or composition). This implies that first we initiate a structural organisation system represented through a graphic 2D or 3D material that we believe has the qualities and potential to absorb and match the complex forces of the real-life situation and to be a source material for a design intervention. Then we start to analyse and clarify the structures of the

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[67] For a critique of genetic architecture see Greg Lynn, Animate Form (Lynn, 1999)

graphical input material and interpret them through codification. Codification means connecting forces to the structural entities. At last we move towards spatial and programmatic organisation and concrete solutions through matching, modification, and negotiation of the systemic entities and principles to the different time-based stages of the real-life situation that is under modification. That means, we start with a structural array, and end up with design.

3.5. RECODING, TRANSLATION AND INTERPRETATION

The manipulation and re-reading of emergent material is a central part of the generative process. Through a set of graphical or other media transformations we gradually develop an understanding of the material and simultaneously we derive and develop the application of the material into artefacts, systems and environments. Several different elements are at stake in these processes:

- Manipulation of data: Simply altering the appearance of visual material will induce re-reading and the emergence of new structural organisation and interpretation of the material.

- Recoding: The data is altered so that it is possible to read it with different software. Recoding is a computational process and does not involve interpretation as such. But interpretation can follow recoding.

- Translation of data: The remodelling of information from one representation to another. This is a design process that involves simultaneous interpretation. For example, Chamberwork's physical model.

- Interpretation: The analysis of a material during and after translation or after recoding. The re-understanding of a translated or recoded material. Interpretation is the process where we decide how to understand the material.

The type of emergence and inspirational design approaches which are in focus here are both open-ended and "open-started" when it comes to meaning and content.
There is no fixed intention at the beginning and the result is not anticipated. Both structure and meaning or content will be altered during the process.

Recoding:

If we look at digital information on the most basic level, the level of bits and bytes, we can regard it as being generic without any fixed meaning at all. It is just bits and bytes. This low level information has to be translated to a higher level of representation to be of any use for the vast majority of computer users and even programmers. The information is presented in a certain way to make it accessible as programming code, text, music, visual material and much more. The recoding happens when we read the information with software. Reading the same information with different software will alter not only its appearance but detach it completely from its original meaning and open it for reinterpretation in its new state [68].

Figure 21   Recoding: A GIF image file of the size 5x5 pixels to the left is on the right read as ASCII-code with a normal text editor. The same data appears in completely altered way by just reading it with different software. The process of recoding does not involve interpretation but the results are interpreted afterwards. The strange poetry would in a generative process operate as the source material for a written text, some kind of strange digital Dadaism or concrete poetry.

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[68] Robin Evans writes about the nature of translation where he states that though translation meaning *to move something without altering it* this is a naïve delusion. Any moving of information will alter its meaning and not the least how it will be interpreted. (Evans, 1997)

Interpretation:
Meaning appears to be inherent in representation. Even when we talk about abstract material that only represents structure, layers of meaning force their way into our perception. When information is represented in a particular form that we can access, it immediately places itself in a field of associations. The little GIF image (Figure 21) could be associated with some modernistic artwork and the textual representation of the image brings association to some strange poetry. Recoding is inevitably followed by reinterpretation. But the altering of meaning we are talking about here emerges because of the transformation of the information-set into certain media categories, in this example, image and text. We have preferences of how to interpret these categories, (e.g. image as art-work, text as poetry) which immediately bias our interpretation. The above information represented as pixels encourages us to interpret the information as a visual composition. Our preconception of the media used to present the information dictates the meaning it generates.

The level of meaning we are talking about here is the generic association to an expressive medium (visualisation, writing). Having said this, and the fact that we read the information from within the perspective of the chosen media category, the information appears as structurally non-figurative and mostly abstract. Associations and incitements for changing the material are easily triggered. Therefore such material acts like a "sponge" towards representational content (program and symbol) later in the process.

A case: Tidsrom

An experimental cooperative project involving architects, designers, composers and scientists founded by the Norwegian Cultural Foundation[69].

Tidsrom:
Christian Jaksjø, Johan Bettum, Birger Sevaldson, Kim Baumann Larsen, Trond Reinholdtsen, Eivind Buene, Gergely Agoston

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Intentions
The intentions of Tidsrom were to develop and rehearse the exchange (recoding) of information structures between different forms of realisation. The collection and development of a structural data set and the development of diagramming techniques were additional intentions of the project.

Techniques
Data collection strategies, data recoding, diagramming, programming,

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[69] Tidsrom was initiated by the composer Christian Jaksjø

Tidsrom was an interdisciplinary project that sought to explore the relation between space and time (Completed in April 2000). This was an experimental study involving seven persons with different backgrounds: composers, architects and industrial designers. (In addition there were some other professions involved for shorter periods, a construction engineer, a computer animator and a scientist) Crudely stated, composers work with a time-based medium (sequential dependent) while architects and designers primarily deal with spatial organisation. The basis for the project lay in an interest in both time and space in both groups. (Sevaldson, 1999b)

Two types of source material were used. In the preliminary study a small computer program was scripted to produce a list of numbers used as source for recoding. In the second study a common database was used as the source material for a number of very divergent computational processes. This database was created by the simultaneous observation and counting of certain features in the environment by eight persons (agents) at the same points in time. The idea was to create a shared time space experience. The construction of this database is of less importance. We will concentrate on the recoding and translation of the data. These processes can be roughly sorted into two main streams: computational processes resulting in 3D spatial constructs and computational processes resulting in auditive spatial constructs.

Examples of recoding of data:
In study 1 of the Tidsrom project, the recoding of data between sound and spatial representations was investigated. The study aimed to develop tools for this exchange process to create a bridge between the different disciplines represented by the project members. First a source material was produced by a PERL script that performed feedback, copying and filtering operations on a string of numbers. The resulting list of numbers was regarded as raw material for any later realisation (Figure 22).

example 1-2 (exert)

```
f1 0 4096 10 1
f2 0 4096 5 .01 4096 1

i1 0.00 0.14 261 1.000
i1 0.14 0.29 329 0.400
i1 0.43 0.43 391 0.200
i1 0.86 0.14 523 0.300
i4 1.00 0.33 391 0.100
i4 1.33 0.67 329 1.000
i2 2.00 0.11 261 0.200
i2 2.11 0.22 391 0.300
i2 2.33 0.33 493 0.400
i2 2.67 0.11 587 0.200
i2 2.78 0.11 493 0.300
```
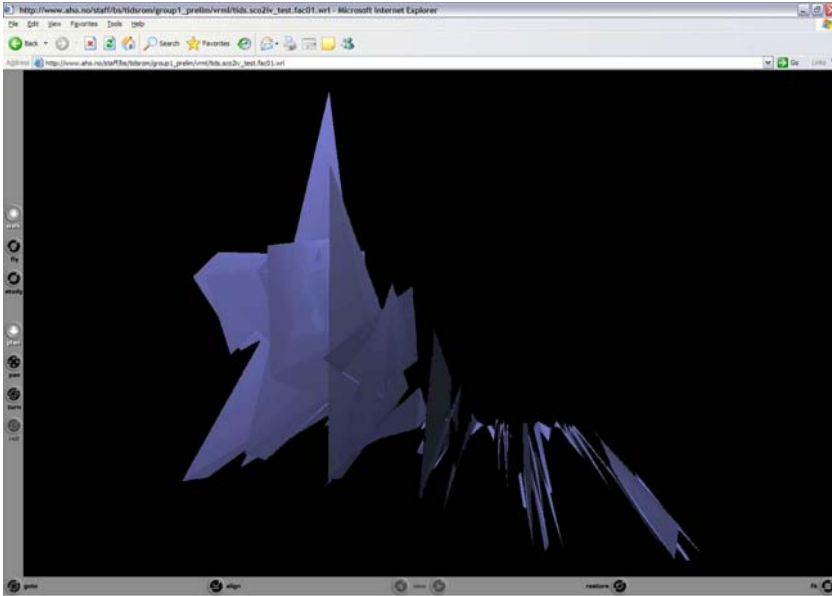
Figure 22 Part of the source material.

This source material was then recoded to represent both sound and space.
The numbers were filtered and matched with vertices in 3D-space in the
Inventor format. This was relatively easy to do because there is continuity in
the data. Three number series from the source material were used to inform
x, y and z-positions for the vertices of the 3D space.

In the second stage in this investigation, we developed different methods for
exchange of digital data from sound files to 3D spatial files. This was
possible because of a match between the data needed for each realisation.
Representations of sound and polygonal geometries are structured in
numerical arrays in the data file, which made recoding possible. Both
representation forms can have large amounts of data. It would, for example,
be difficult to translate sound into rule-based geometries since there would be
a mismatch between the amounts of data[70].

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[70] Typical rule based geometries would be describing a cylinder with three numbers:
the radius, the sweep angle and the height. The sound file with thousands of digits and
the rule based geometry with only a few digits are difficult to match.

Figure 23 Example of a 3D realisation of the source material. Inventor file displayed in a VRML viewer plug-in.
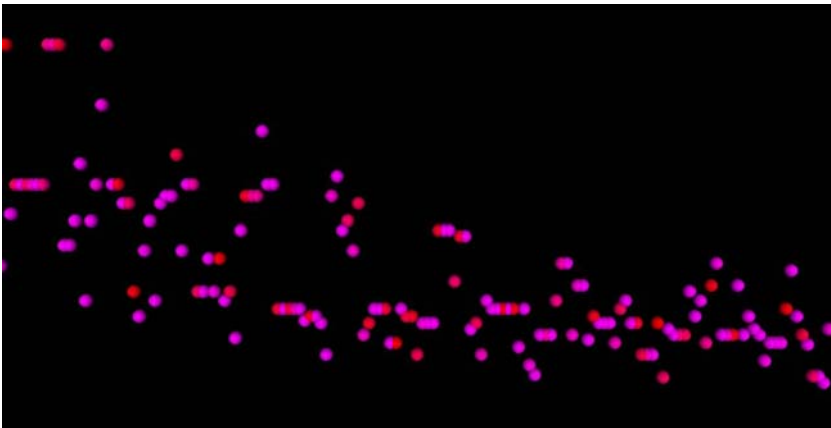
Figure 24 The first models where merely mapping points in space, not rendering any relations between the points.

The Inventor format was chosen since it is one of the most accessible 3D-formats and in addition an open format. (It is similar to, but simpler than,

VRML) Various methods of mapping the diverse sound parameters to spatial construct were developed.

Two principally different ways of representing sound-material in 3D-space were developed: in the first models, sound data was represented as points in space only and no relation between the points was established. (Figure 24)

In a further development of this model, additional parameters where mapped to colour information and radius of the spheres representing the points in space. (Figure 25)

These models however did not show any relations between the points. Relations are inherent in the files when they are read sequentially. The sequence is an important factor in the sound files. Establishing connections between the points resulted in polygonal geometries showing which points were related.
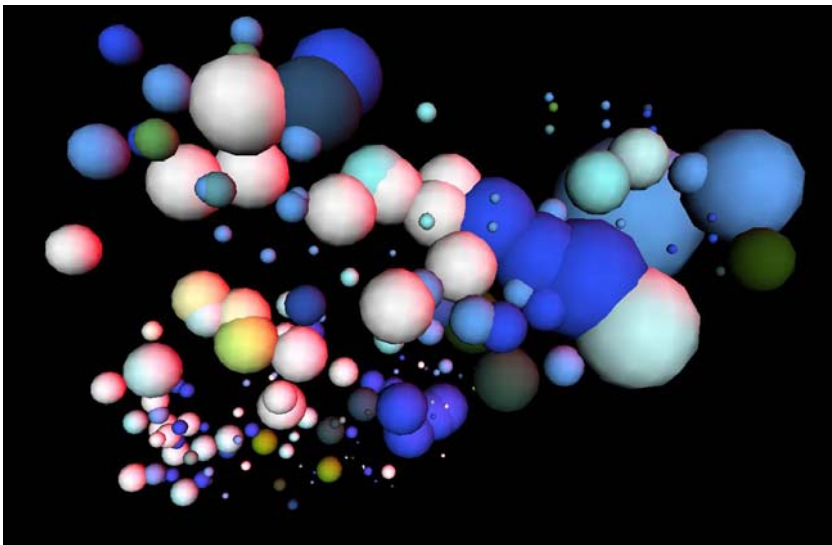

Figure 25 A further development of the point model included additional parameters from the sound files to be rendered. These parameters informed colour values and radius of the spheres representing the points.
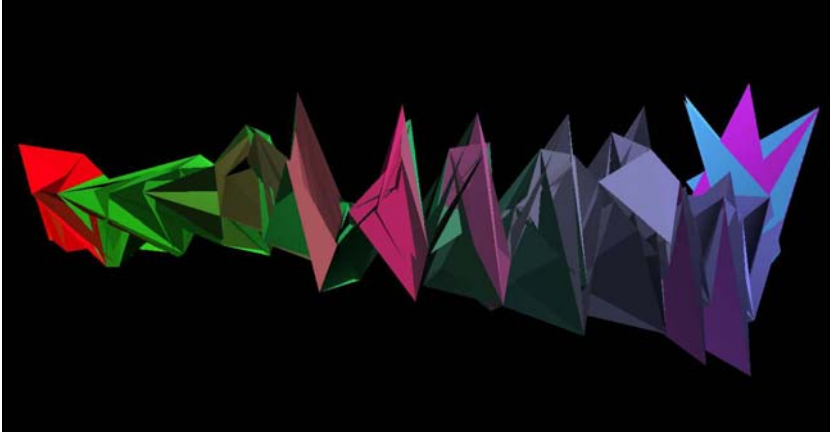
Figure 26 The next generation of models displayed the relations between the points. The model shows the same data set as above.

This technique was developed and tested on increasingly complex source materials (Figure 27, Figure 28). The visualisation of the sound files revealed some structural relations in the files that are not perceivable from listening to the original files. And vice versa, the 3D files were not directly informative as to how the represented sound files actually sound. The recoding process maintains a relation but at the same time it generates something new and not entirely anticipated.
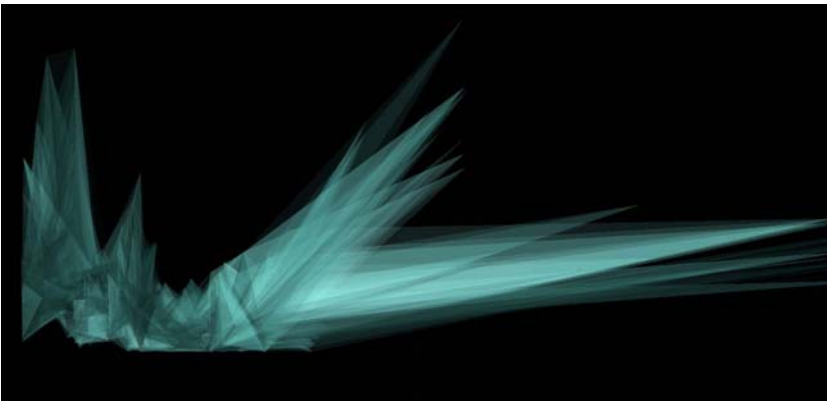
Figure 27 The models were developed further and much more complex sound files and relations within the data were explored.
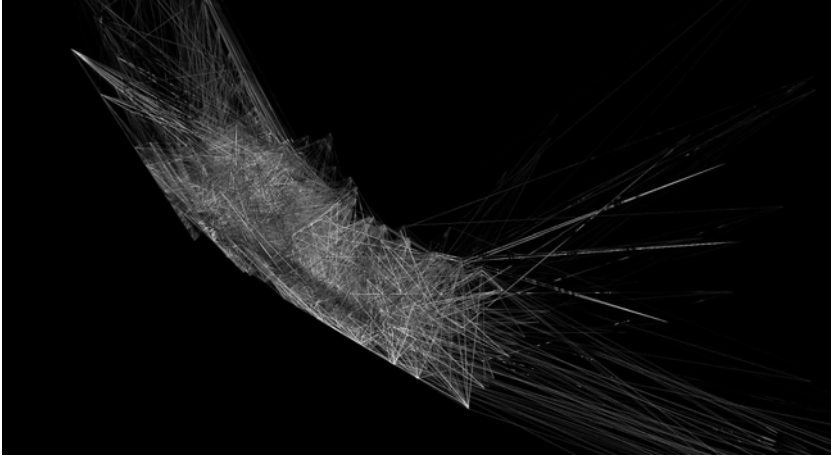
Figure 28 Rendering techniques that would help to investigate the models were explored. In this test, a wire model was texture mapped to create an effect that would make it easier to distinguish a large number of wire threads in very complex models. (Rendering: Kim Baumann Larsen)

The experiments that investigated the interchange of data between two representations, sound and graphical representation resulted in a number of small programs that were written especially for the task. The members of the study group conclude that:

> This way of working operates on two levels: A virtual abstract field (structure as numbers) and a concrete interpretational field (structure as image or sound). This concept makes it easy to switch between different realisations and it should be possible for artists in different fields to cooperate and exchange material. (Larsen and Reinholdtsen, 2000)

In their conclusion, they also point to the questions of the source material. There are basically two principles of producing source material. It could be produced in a (computational) process or it could be found material. In this study the material was produced with a PERL script, but the investigation lead to further experiments with found data.[71]

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[71] For a more detailed report on the techniques and detail of the programming process read the report from the study at:
http://www.aho.no/staff/bs/tidsrom/group1_prelim/tids.doc_study1.rep.pdf

Translation example:

Spatial diagrams of event envelopes.

The studies so far produced two kinds of spaces, the edgy polygonal spaces and the spaces with vertices representation. I wanted to investigate other possible spatial representations of the dataset. In the following experiment, the intention was to render the events diagrammatically as geometric cones indicating a potential for further events to take place (event-cones). The aforementioned database collected by the eight "agents" was used as a source material for the translation exercise.

The translation process resulted in an exciting rehearsal in diagramming a highly abstract feature of an event: the potential for bifurcation of a sequence of events; the potential for something else to happen. The idea is that for example when a space continues through several doors leading into diverse adjacent spaces this represents a higher degree of potential for a bifurcation of events than if there is only one door. This is also applicable to the number of people in the room or other entities. So by counting these "triggers" we can establish a measure of the richness of the space in respect to what amount of possible events that could follow from an occupation of the space.

The result of this work is more diagrammatic than the recoding approach which was more structure based. Also there was a predefined intention for the resulting form of the translation. The intention was to create spatial diagrams that reflected the events and included features such as potential triggering, duration and sequence. The duration of being exposed to a trigger would inform the trigger's force and the sequencing would register the sequence of exposure to the trigger.

While the previous examples were based on automated recoding, the experiments which followed were based on manual modelling: translation. The interpretation and imagination of how the data could be represented followed the modelling process throughout the work from the beginning. It started with a "cleaning up" and reduction of the database.

Each agent's data was mapped onto a coordinate system rendering rich possibilities as to the number of triggers. Time was split into two additional parameters: sequence and duration. Triggers (number of doors, number of windows and number of people) where mapped onto the XYZ coordinate system, producing points in space. Sequence was rendered with a line connecting the points according to their initial registered time. Duration was rendered as radius creating the geometry for the construction of event cones. The whole set of cones was called *event envelopes*. Long duration produced a wider event cone with larger volume which diagrammatically indicated a greater possibility for the triggering off new events.

The project database indicates a common time span for the experience of four actors (agents) who during the registered eight hours never met. But through the simultaneous registration of three identical features in their surroundings they share a common cognitive space.

The original database shows agents with registered duration of events, listed according to sequence in time (Figure 29).

Samtlige agenters data, samlet og sortert:

Tid			Omgivelser:			Mennesker				
Fra:	Til:	Varighet:	Dører:	Vinduer	Vindu/dør%	Menn:	Kvinner:	Sum menneske	Notat:	Navn:
08:00	08:15	00:15	1	2	200,00%	1	0	1		Nils
08:00	09:30	01:30	1	1	100,00%	1	0	1		Christian
08:00	11:00	03:00	1	1	100,00%	1	0	1	Sleeping in	Gergely
09:05	09:30	00:25	2	1	50,00%	1	0	1	Johan	Johan
09:15	09:30	00:15	1	2	200,00%	1	0	1		Nils
09:31	10:00	00:29	1	1	100,00%	1	0	1		Christian
10:00	10:30	00:30	1	2	200,00%	1	0	1		Nils
10:01	10:10	00:09	1	1	100,00%	1	0	1		Christian

Figure 29 The image shows a small part of the database. The vertical axis describes sequence, while the third column from the left is duration. The next columns show different triggers.

Since the intention in this study is to generate a diagrammatic event envelope for each agent separately, the database was sorted according to agent. The date was "stretched" from integer to floating-point numbers through the appliance of a simple rule. All registered data was multiplied by the ratio between windows and doors. (Figure 30)

Series N

|	time	08:00	08:15	08:30	08:45	09:15	09:30	10:00	10:30
	regression value								
	duration sec	30	15	15	15	30	15	30	30
	delta duration sec	1425	1275	0	15	1430	15	1	2
X		500	200	200	300	200	200	200	200
Y		833	400	400	900	400	400	400	400
Z		333	200	400	1500	400	200	400	200

Figure 30 Remade database.

Spatial modelling
The modelling of diagrammatic spaces from the source material was based on duration being the most important modulation parameter. The construction of the diagrams was done in two variations. In both cases the

global coordinate system was configured around a graph of possibilities: interpreting number of windows, people, and doors as triggers for possible influences, interactions and gates to further experiences (events). These three parameters where mapped along the x, y and z axis in a Cartesian space.

In this system the events generate points in space along a line operating on a 3D scale from less to more possibilities. The points were connected to register their order of succession. (Figure 31)

The duration of each event is an important factor to "measure" the potential impact of an event. Duration was expressed in two different ways, along an axis and as a radius value.
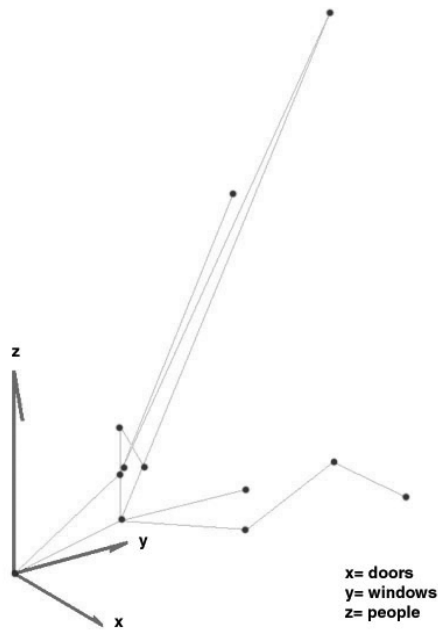
Figure 31 The illustration shows the mapping of events in space and the time-based relation between the events drawn as a blue line indicating the sequential order of the events.

System 1
In System 1, a duration axis was placed along one freely chosen axis. The distance of the point from the axis was used for radius and the duration value for sweep angle. Sweep angles exceeding 360 degrees were ignored. This system rendered duration according to degree of possibilities measured in

two of the x y z parameters. The more possibilities the more the duration was weighted (increased radius).

The weakness of this system is that it does not implement duration that exceeds 360 degrees nor does it involve more than two of the x y z parameters when rendering the duration circle.
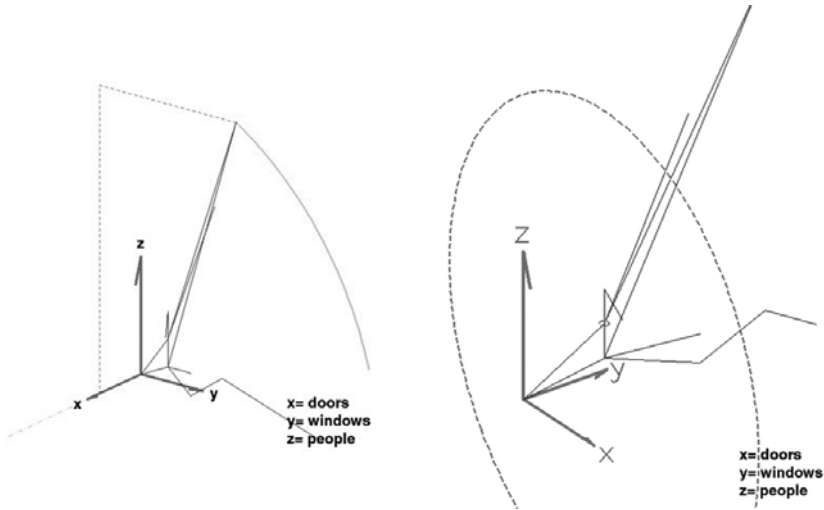

Figure 32 To the left: System 1 based on the mapping of duration to sweep angles. To the right System 2: mapping of duration to radius.

System 2
The Second system rendered duration as radius for each event. This produces a diagrammatical event envelope which is easy to understand. The generated space frames a volume of possibilities directly: long duration = big volume, short duration = small volume. A disadvantage is that it does not weight the events space according to increased possibilities. (Sevaldson, 2000b) [72]
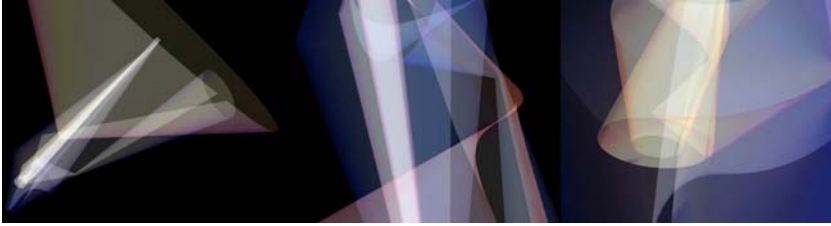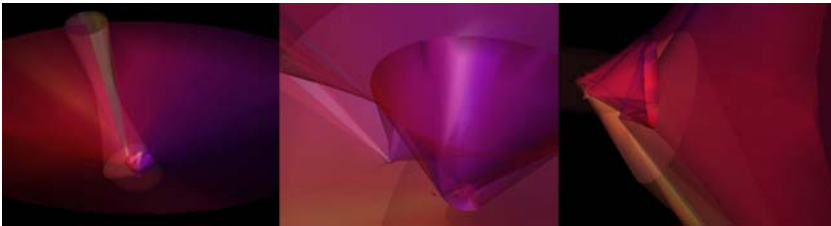Below are illustrations of System 2 event envelopes.

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[72] For the complete report from this study go to:
http://www.aho.no/staff/bs/tidsrom/envelopes/report.pdf
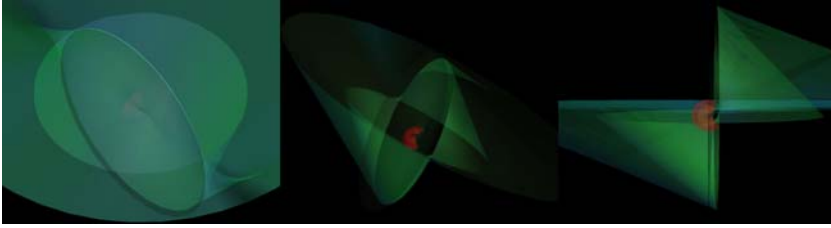
Figure 33 Event envelopes for agent Christian.

Figure 34 Event envelopes for agent Gergely.

Figure 35 Event envelopes for agent Johan.

These recoding and translation experiments demonstrate the difference between recoding and translation. Recoding generates new forms from basically the same data. This lets us experience certain inherent qualities of the data that are not visible in its original form.

Translation involves interpretation and intentions from the beginning. It involves a simultaneous engagement and visualisation of the data.

The fact that data are relatively easy to translate, manipulate and process, opens up for the facilitation of the computer's true potential which is not merely representation but involves creation through emergence.

3.6. RECONFIGURING SCHEMATA

Emergence is attractive especially to those designers and artists who allow the creative process to be inspired and to a large degree driven by external input, as opposed to seeing creativity as an internal process. For such designers, inspiration comes in the form of impulses and findings in the real world. The obvious reason for being attracted by computer technology is the possibility of producing this external input with a machine. As mentioned, an important effect of the graphical techniques applied to abstract data sets is the production of unexpected solutions. The unanticipated is exactly what this type of designer seeks. They seek it for inspiration and to find solutions they would not have arrived at if they had solely depended on their internalised knowledge, intuition and skill. This knowledge and skill and even complete processes, are framed in experiential categories called schemata. Gelernter, following Piaget's concept, (Gelernter, 1988). The notion of schemata is used by Piaget as an explanatory model of the process of understanding the environment. This model was related to design thinking by Mark Gelernter :

> In both acquiring new knowledge and developing new skills, the mind works from a repertoire of conceptual schemata (programs of conception or action) which in the past have enabled individuals to negotiate problems successfully. Whenever the individual faces a new situation, a new piece of information or a physical problem, he or she first tries to solve it with one of the schemata from this existing repertoire. Should one prove to be successful, the problem is said by Piaget to be assimilated by the schema. On the other hand, if no existing schema will make sense of the new information or enable the individual to negotiate the physical problem, then the individual begins to search through the repertoire for a schema closest to the action or understanding he or she desires. By testing an existing schema against the problem, adjusting the schema in light of its success or failure and then testing again, he or she eventually might develop a new schema which will cope successfully with the new problem. A schema which has been evolved to cope with a new problem is said by Piaget to be accommodated to the problem. Once developed, a new schema is put back into the repertoire for possible future use, and in this way an individual's understanding and skill grows ever more extensive (Gelernter, 1988) : 41-42)

Schemata are necessary for our survival. We understand and act in response to the environment according to learned experience (schemata). But our preconceptions need to be challenged when we seek new solutions in our response to the environment. Schemata make us efficient and experienced designers as we have a repertoire or palette of means, tools and processes that we can use over and over again. But schemata may overshadow other less obvious and more original and creative responses. The use of

electronically produced emergent material in a design process turns out to be a potential technique to break established design schemata.

Robin Evans has a similar discussion but he relates it to language citing the poet Paul Valéry: "…seeing is forgetting the name of the thing one sees" (Evans, 1997). This quote clearly refers to the schemata discussion above. Language being full of established concepts types and categories often obstructs the visual experience with preconceptions. But Evans goes on to argue that by removing language on the grounds that this contaminates art with other forms of communication would lead to an "enclosing of architecture within its own compound" to preserve its integrity. However, he thinks that this is unlikely to occur because of drawing, the "unfailing communicant". Though the connection to my proposed anti-schemata strategy is unclear, in Evans text it relates to the issue of the archetypes, categories and terms having a powerful influence on how we act as designers. But I am not sure about his belief in drawing as communicant. Terms are linked to archetypes, figures, and hence drawings and the concept of schemata embraces all communication forms. That is why I prefer this perspective. (Evans, 1997)

The concern about preconceptions is well-known in for example electronic music (Barrett, 2004), but few designers comment on this issue. Alejandro Zaera-Polo from Foreign Office Architects describes it this way: (Zaera-Polo, 2002):

> We want to 'unexplore' the materials, and here we should understand material in the broadest sense, as a source of ideas and effects. Processes are far less constraining than ideas, which are inherently linked to extant codes that operate critically, or in alignment, with pre-existing etymologies.

The most interesting text I found that relates to this issue is Peter Eisenman's Diagram Diaries (Eisenman, 1999a). Keeping in mind Evan's statement that the drawing's power is in its lack of resemblance to what it represents, the diagram in Eisenman's text can be seen as a consequence of Evan's statement. But once more, with reference to language and figurative archetypes, Eisenman sees it as important to resist and overcome the motivated sign:

> The idea of overcoming the motivated sign (…. …) is a critical project for the diagram. Here, the diagram becomes an agent for the movement towards the becoming unmotivated of the architectural sign. (… ….) In order to act diagrammatically, the diagram must first overcome the motivated conditions that are at the root of architectural discourse. Equally since architecture is a productive

discourse in that it must structure, enclose, shelter, etc., these motivations can never be completely negated. What the diagram can do, however, is destabilize such motivated conditions as site, program, function, and meaning….

This introduces the strategy of the diagram as a negative or resistant agent. In this context, the diagram begins to separate form from function, form from meaning and architect from the process of design.

This powerful text continues with a discussion on the problems of 'the negative' as a mission and the resulting desire of fulfilment. Eisenman states that the diagram resides between the project and the author's desire for fulfilment. Eisenman's 'mission of the negative' is similar to the strategy of resisting schemata. We need schemata but we need to resist them. I still prefer to use the term schemata instead of the sign. Schemata is a more generic term, not only embracing communication but also actions and events as we will see later. [73]

In many creative techniques the necessity of breaking established conventions and rules, in order to reach new insights or results, is regarded as important. There are numerous ways of achieving what we could call the breaking and reconfiguring of schemata. All of these techniques are designed to loosen up "mind control" when dealing with design problems. The most known technique is "brainstorming" where spontaneous expression functions as triggers for the group to spin off new solutions. Brainstorming is to be conducted in a state of little rational control; rather the participants need to be spontaneous, suspending any critical attitude. Other techniques suggest searching for inspiration outside of the known fields to fertilise otherwise familiar and repetitive processes.[74] Using natural phenomena as sources for inspiration is known both amongst designers and engineering[75]. Common for many of these processes is that they require a phase of translation. The found source material is not directly applicable but has to be processed.

These and similar techniques are generic techniques which can be successfully conducted either with traditional methods or with a computer. But the computer is superior to any traditional method when we consider its power to generate, support and trigger emergence. Another important feature of the computer is its flexibility, which allows quick altering of the input material, the set-up and the parameters. Also the computer is superior in its ability to process very large quantities of a source material in very short time.

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[73] See part 5 in the chapter about time-based design.

[74] Greg Lynn suggests experimentation with non-architectural schemes especially to develop means to deal with time and motion in design. (Lynn, 1999)

[75] One example from engineering is the centre for Biomimetics at the University of Reading UK http://www.rdg.ac.uk/Biomim/

The output from the computer can be understood and interpreted in many different ways. It could be used for visual decorative effects, as has been central in the development of graphic design. Or it could be used to inspire associations, like when we find forms in the clouds. In our work, we constantly tried to develop ways that would engage more deeply with the material on several levels. We regarded the source material on formal, abstract and structural levels. The material therefore was used for example, as form-generators or form-templates for specific design problems, or it was used as underlay for organisational systems, principles of relations or intentionally uncontrolled features in a design. Also for rendering programmatic distribution, principles and systems scenarios the technique seems to have potential. In all these cases the human is central. The designer constructs the set up and initial conditions. He is also central as interpreter and selector.

In the design of the layout for Tøyen Park in Oslo in the project "Ambient Amplifiers" the application of an uncontrolled source material and the following negotiation between that material and the existing conditions on the site, resulted in very unexpected solutions and the invention of a new concept, the "Programmable Street". These solutions would definitely not have been reached within the frames of a traditional design process, where the "Island"-attractors and the street layout would have followed lines of pre-conceived functionality and learned composition skills.

Figure 36 Breaking schemata: the negotiation of a "wild" generative material resulted in several inventions in the project Ambient Amplifiers. The source material, here already processed, collided with both existing street systems and property borders. This initiated the re-articulation of the street and eventually triggered the invention of the "Programmable Street". Also the fence to the Botanical Garden to the left was reinvented to become a flexible border condition where the seemingly awkward placement of one pavilion right on the fence resulted in the configuration of that pavilion as the main negotiation device. The concepts were tested with four possible scenarios. (A project description is found in Part 5)

3.7. RULES AND GAMES

While the aforementioned techniques will give a creative boost, it is questionable whether they will maintain creativity in the long run. In our conversation, Natasha Barrett raised some central questions that also confirm that the same issues of breaking schemata are at stake in musical composition:

> With what criteria do we decide to follow one path and not another? Once a path has been selected, further stages of discovery become easier. But what seeds the initial choice? Beginning from a completely blank sheet is rarely possible. We have preconceptions, tastes, and most likely have an abstract idea of what we are looking for and through experimentation discover how to make the abstract gradually more concrete. How can we stop our preconceptions 'blinding' us to 'fresh' discovery, or prevent our current (old?) taste inhibiting our awareness of what is emerging in the creative process? (Barrett, 2004)

A technique I have tried on several occasions is to set up strict rules for a process and follow these rules over time without interfering or responding to any output until a later stage. By implementing a "mechanical" procedure to certain chosen parts of the process one ensures that no preconceptions bias the production of an array of solutions through "unconscious" selection. In these processes I regard detachment and distance as important as inspiration and creation. Rigid "mechanical" processes provide detachment and order. Rigidity is applied in the adjustment of the parameters and the sorting of the output material of an emergent process that in itself often has a "wild" and untamed nature. Or as Greg Lynn puts it:

> ....the computer brings both a degree of discipline and unanticipated behaviour to the design process. By negotiating the degree of discipline and wildness, one can cultivate an intuition into the behaviour of computer-aided design system and the mathematics behind them (Lynn, 1999).

In a rigid and systematic investigation of the effects produced by the manipulation of parameters in a computer model, the result comes as arrays of instances, stopping frames of animations or sections through time or space. Without any regard to preferences or anticipated solutions, a pre-chosen interval of the parameter variables may be produced. Only when all possible solutions according to the set-up of the input parameters have been produced are they evaluated in respect to formal issues and potential use. The parameters could be as simple as colour values or filters in Photoshop that are moved in regular steps to produce a series of images that can be compared and investigated to find unanticipated results.
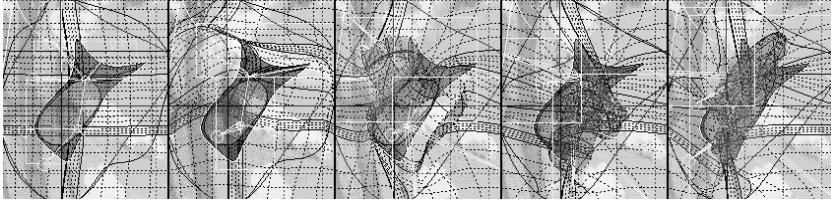
Figure 37 Stopping frames from a continuous deformation of the field conditions around one attractor. The interval between the frames is 10 frames, constituting a selection rule for the material. From Ambient Amplifiers. (Birger Sevaldson 2000)

The manipulation of visual structural information in this mechanical way might easily lead to the development of more-or-less strict rules. The potential of the visual material is unfolded systematically through these rule-driven investigations. All design projects are to a certain degree about defining internal logics and rules. In this sense there is nothing peculiar about such an approach. What is special is the degree of rigour and the way we let these rules play their own game before we interfere. Since all visual material represented in computer software is, to a certain degree, driven by parameters, it is easy to systematically alter these parameters. The simplest examples of such parameters would be brightness and contrast or hue and saturation in image-processing software. Since these parameters are gradients on a numerical scale (often with 256 digits) it is easy to systematically alter the parameters.

In the experiment in figure 38 I began with white noise.[76] A noise-filter was used on a white canvas of 300 x 300 pixels in Photoshop. The result is shown in the second frame in the top row. The next step was to crop the canvas to 100x100 pixels and to enlarge the image back to 300x300 pixels (third frame in top row). Then the procedure began again from the beginning: the same noise-filter was used (see the fourth frame in the top row) and the same cropping and scaling (first frame, second row) and so on. This produces fields of increasing complexity until a certain point when the process seems to stagnate (third frame, third row). This experiment suggests that rigidity sometimes comes at a cost while a freer approach can produce more interesting results.

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[76] This experiment is inspired by a lecture of Olav Havnes a writer and programmer and partner of Orgdot. http://www.orgdot.com
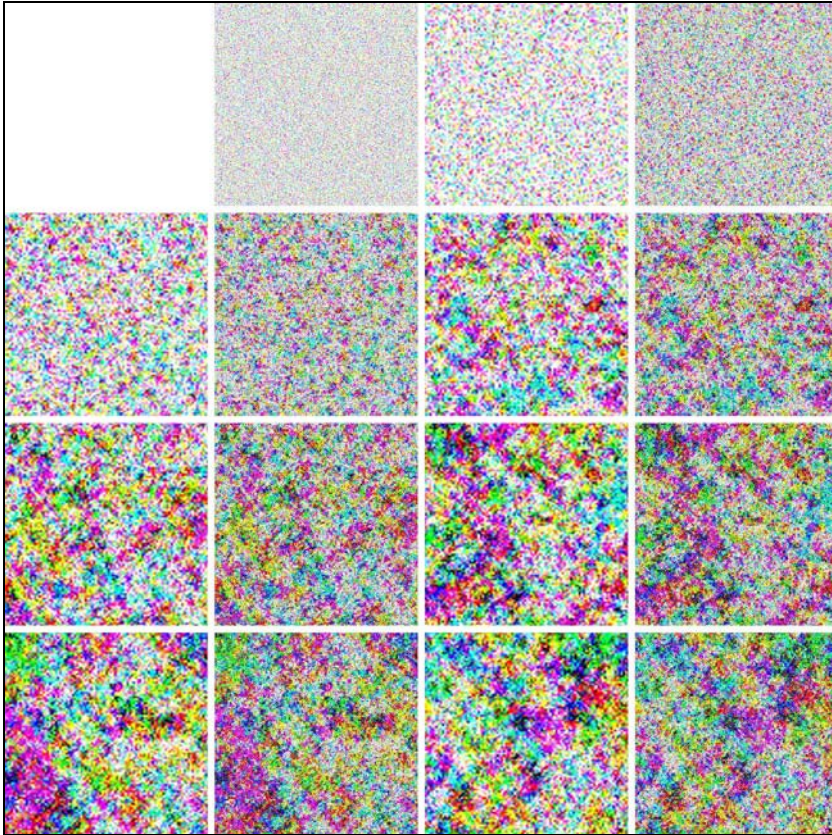
Figure 38 The rigid approach will in many cases only bring us a limited way forward despite its potential for discoveries. In each step the same rules with the same parameter values are applied.

Is this a general phenomenon of evolutionary design? Here I think it is necessary to return to Manuel DeLanda's comment (DeLanda, 2002):

> When one looks at current artistic results the most striking fact is that, once a few interesting forms have been generated, the evolutionary process seems to run out of possibilities. New forms do continue to emerge but they seem too close to the original ones, as if the space of possible designs, which the process explores, has been exhausted. (DeLanda, 2002) : 11)

In the experiment below (Figure 39) exactly the same rules were used except that the cropping of the image was not rigidly set to be 100x100 pixels. Instead the most interesting fields of the images were chosen by framing them manually and the zooming was sometimes repeated without applying noise at every stage. So we introduce a searching eye into the rigid process. The eye of the designer searches for the abnormalities, the surprises and the findings that have the potential to operate as gateways for further development.

We start from the frame of the former experiment where the process seemed to stagnate. Particularly at first, much smaller areas than 100x100 pixels were chosen, resulting in much clearer formations. The horizontal striation of the images appears from the selection of vertical stripes of the image that were stretched when scaled to 300x300 pixels. The results are more interesting and beautiful than in the rigid experiment.

The appliance of rigorous rules put the designer into a state of disinterest and openness towards unanticipated output. Preconceptions (schemata) are temporarily blocked out. Though preconceptions or an intuition developed through extensive use of computer software would influence the set-up and selection of material and parameters, mechanical and systematic state of filling in the matrix would to a certain degree, secure the breaking of the preconception.

For allowing the emergence of the unanticipated, we need in periods to rest in a state of disinterest and detachment (a well-known tactic amongst some painters)[77]. Although rigour has advantages, it also has limitations and we are free to interfere at any stage in the process. Interference and rigour can go together when we evaluate and change the course of action at a certain frequency during the design process.

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[77] The unanticipated is of course relative to the schemata.
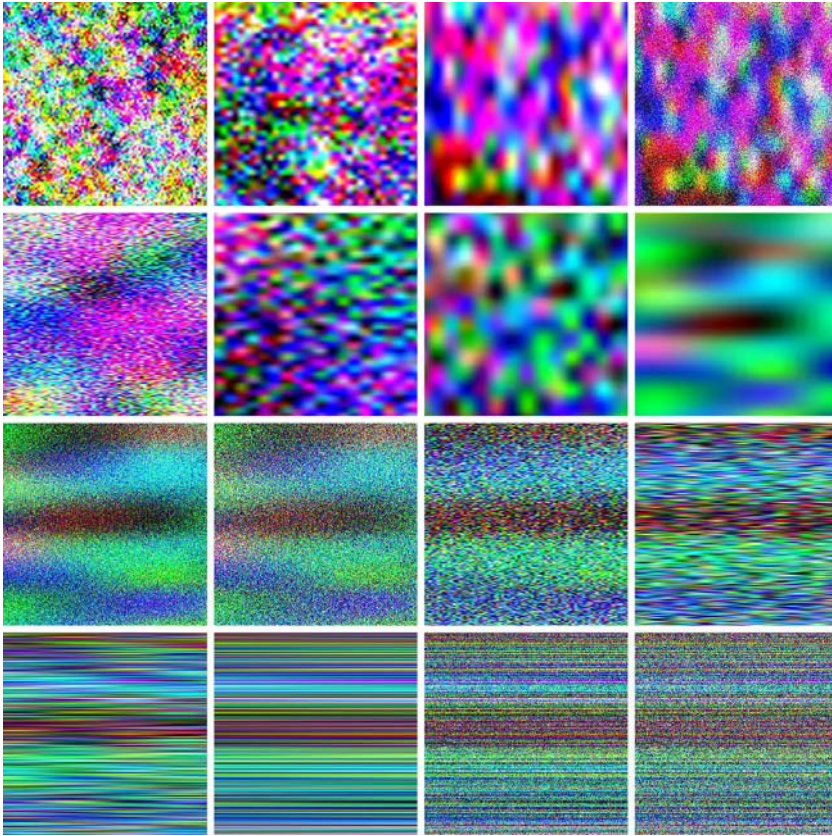
Figure 39 The combination of rigid investigations and free play makes it possible to challenge our preconceptions and arrive at unexpected solutions. Here the rules from the former experiment (Figure 38) are still the same but the parameter input is altered freely for each step.

In the long run, a process where the subject is engaged is much more potent and productive than a strictly rigid process. This thesis is based on the exploration of these interactive processes.

3.8.1. What is "The Virtual"?

An inclusive though diffuse definition would be:
Existent due to power of possibility.

The virtual is surrounded with confusion. Many parallel interpretations are intertwined and it is therefore difficult to simplify this issue unless one defines in a particular perspective. Greg Lynn 'writes in "Animate Form" that:

> The term *virtual* has frequently been so debased that it often simply refers to the digital space of computer-aided design. It is often used interchangeably with the term simulation. Simulation, unlike virtuality, is not intended as a diagram for a future possible concrete assemblage but is instead a visual substitute. "Virtual reality"' might describe architectural design but as it is used to describe a simulated environment it would be better replaced by "simulated reality"' or "substitute reality"'. Thus, use of the term *virtual* here refers to an abstract scheme that has the possibility of becoming actualized, often in a variety of possible configurations. Since architects produce drawings of buildings and not buildings themselves, architecture, more than any other discipline, is involved with the production of virtual descriptions. There is one aspect of virtuality that architects have neglected, however, and that is the principle of virtual force and the differential variation it implies. Architectural form is conventionally conceived in a dimensional space of idealized stasis, defined by Cartesian fixed-point coordinates. An object defined as a vector whose trajectory is relative to other objects, forces, fields and flows, defines form within an active space of force and motion. This shift from a passive space of static coordinates to an active space of interactions implies a move from autonomous purity to contextual specificity. Contemporary animation and special effects software are just now being introduced as tools for design rather than as devices for rendering, visualization and imaging (Lynn, 1999).

As this thesis crosses some borders between disciplines, it is useful to interpret the virtual in a broader sense. A valuable source for an inclusive review of the virtual is Rob Shields. In the twentieth century the virtual or Virtualism was based on the computerised utopian mass culture though Shields point out that the digital virtual still feeds on the historical forms of the virtual. Shields mentions some of the key definitions of the virtual through history. He points to the historical roots of the virtual. These include the virtual as 'essence' as well as 'virtue' (Shields, 2003). He also points to

the connection to the baroque, the Christian reformation and to rituals. Writing a thesis on computer-aided experimental design techniques, it is impossible to base a discussion of the virtual on a simplified, precise and exclusive definition. In this thesis we will keep the different aspects of the virtual in mind but I will also in the following develop my own perspective on the virtual.

3.8.2. Virtual reality

Over the last decades the concept of virtual reality (VR) has referred to computer-generated simulation of 3D environments. While VR might stand for computer-based representation of real spaces reflecting our own physical environment more-or-less directly, (verticality and horizontality, domination of horizontal movement, gravitation) this is not a very correct or inclusive conception of "the virtual". If we interpret virtuality according to its historical meanings, this may help us to reinvent the use of the computer for many aspects of the design process. Shields points to the parallels between digital virtuality and liminal rites of transition (Shields, 2003). These rites were "social spaces of transition" as Shields calls them. Shields argues that these spaces derive from the liminal but that they do not entail rites. I am not sure if this is really true if we look at the rituals of contemporary multiplayer role-play games (RPG), where levelling of skills and ritualised and tribal behaviour seem to be a central feature of the virtual growth and adventure of a character that represents a real human.

Virtual reality is a concept that has lost some of its former potential. Shields connects it to cyberpunk, one of the most important countercultural movements since the sixties. This countercultural movement seems to have lost its momentum. Today digital virtualism is the result of mass production in an industry of entertainment that seldom uses the term at all. In everyday language, *virtual* is simply a synonym for *almost* (Cowie, 1989). This is a useful definition to keep at the back of one's mind when considering the enormous breadth of recent discussion on this topic (Beckmann, 1998)

The virtual embraces a wide spectrum of ideas related to (information) technology and its impact on numerous aspects of life and society. However, such a broad understanding of the virtual is of little use to us for the purposes of this thesis. Common for the different interpretations of the virtual is that it is triggered by the emergent virtual spaces made possible by computer technology. If we regard the virtual as almost real, as *existent due to power of possibility* it expands the notion of the virtual beyond *simulation* as found in what we commonly call virtual reality.

I do not totally adopt the use of the term virtual that is found in architectural discourse. I find it disturbingly inaccessible and in disharmony with the

common understanding of the term in other fields. I think expanding the noun *virtual* to include more than simulation but without excluding simulation is most useful. The expansion of the noun *virtual* can trigger a much richer and wider field where we can explore and work with all thinkable modes of representation, all of them representing potential existences for the departure of design.

Investigating "the virtual"

The word *virtual* is of course not exclusively linked to computer technology but the actualisation of the virtual as discussed in design is clearly triggered by information technology. In order to gain a deeper understanding of the concept, I found it interesting to look at the famous painting by Paolo Uccello, 'The Battle of San Romano'. This particular painting is especially interesting for this purpose because it demonstrates several aspects of the virtual. Using a fifteenth century media example helps to detach the principles from the computer media and generalise the term "virtual".

Uccello's paintings are historic in several ways. Most frequently mentioned are Uccello's investigations into linear perspective. Though linear perspective is usually credited to Filippo Brunellschi, Uccello is one of several painters who contributed to its development. (Kemp, 1990) In Uccello´s other paintings we often find architectural elements, which are very efficient and possibly necessary means of investigating the concept of linear perspective. 'The Battle of San Romano' is interesting because it deals with an open-air event with the complete absence of architectural elements. To make it still more challenging, the scene is very complex. Uccello strives to apply the perspective principles that are relatively easy to understand in architectural geometries, to natural forms. In 'The Battle of San Romano' linear perspective is especially concentrated on the lower part of the picture where the battle debris is ordered in a pattern rendering a central perspective. Uccello also introduces perspective shortenings of complex shapes, especially obvious in the body of the dead soldier to the left and the black horse to the right. Uccello, despite breaking new ground in painting, still seems not totally comfortable with the perspective. The background rises far above the horizon and appears more like a backdrop to a theatrical stage than a distant landscape. [78] But despite its partly incomplete perspective representation, the painting creates a *virtual* depth with the intention to mimic real space based on the same principles as computer-based VR systems do to day. The perspective and the image plane were necessary inventions for the three dimensional representation of spaces on the computer.

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[78] For a similar analyses of this picture see (Gombrich, 1972)

Figure 40 Extracting the pikes in Uccellos 'The Battle of San Romano'.

But there is much more to the painting. For our purpose of investigating "the virtual", it is interesting to look at the way Uccello renders dynamic forces and time-based events. The picture is a 'snapshot' of the moment of total defeat. A moment later and the battle will be over. Uccello solved the problem of combining the overwhelming movement towards the right with a balanced composition in several ways. The losing army is represented with only two knights, one of them barely visible; we only get a glimpse of his helmet. The background elements balance the action that takes place in the foreground. This dramatic event is painted in a strictly organised, schematic way, paying respect to the illustration of movement, the demands of the pictorial frame, and the need for a balanced composition. In this way Uccello refers simultaneously to the external world he wants to represent, to the need of abstraction and to the internal 'laws' and state of painting in his time.

One of the most interesting aspects of Uccello's painting is how he induces movement. I wish to argue that this virtual movement in the picture stems from the structural organisation of the pictorial elements much more than from the figurative. The formation and patterns of the graphical objects in the painting create virtual depth and movement. My analysis of Uccello's painting is partly inspired by Ann Sheppard's analysis (Sheppard, 1987). However, I do not share some of the central points in Sheppard's argumentation. In the following commentary, Sheppard confuses the formal and figurative aspects in Uccello's description of movement:

> If we are to look at this painting in purely formal terms we shall have to abstract its shapes not only from the things they represent but also from any notion of movement and depth in space... ...if we manage to see the pikes just as lines slanting forward we will still tend to see them as moving to the right. If we were seeing them in purely formal terms we would do nothing of the kind. (Sheppard, 1987)

It is not easy to grasp what kind of distinction there is in Sheppard's use of the word formal opposed to seeing the pikes as lines slanting forward. In fact

this may be a false distinction since the formal and structural aspects of the pikes would, in their abstracted or diagrammatic form, be rendered precisely as lines. And in contrast to Sheppard's argument, what produces the movement in Uccello´s picture are mostly structural organisation and formal phenomena. The additional typological elements like the horse with legs in trotting position add to the reading of movement in the picture, but the feeling of movement is produced by the structural organisation of the elements in the picture. Ironically the horses are painted in a stylised way where they appear almost like frozen sculptures. The rendering of the horses in a position of movement does not necessarily describe movement itself. Frozen movement depicts stillness rather than anything else. I think Uccello actually failed in illustrating horses in movement or creating an expression of the movement of the horses rather than the horses themselves. To be fair, I think Uccello's intentions are more complex than that. He was struggling with the development of the perspective in organic bodies, and he managed to suggest movement by the means of the organisation of the pictorial elements on the canvas.

The painting indicates that virtual movement is independent of what the forms represent, and that the virtual aspects can be investigated on purely formal / structural terms. Seen in structural terms, the lines configure form by means of direction, density and clustering. If we trace the pikes in the painting as lines, they would still form directions, each of them on its own, but since they form groups because of their density and shared direction, they produce an appearance of potential movement, independent of other elements in the picture. This virtual movement is purely an internal thing not dependent on knowledge of the context. If we rotate the groups of lines they would still render these virtual movements although directions are altered. We do not need to know that the lines are pikes of a forward moving army to see the inherent movement that they depict.

I argue that "the virtual" in painting and art is not found in representation but in the configuration of forms that produce a potential movement and life in the picture. We can analyse these features if we investigate the painting on a diagrammatic level by constructing diagrams that map the densities, grouping and configuration of the elements and produce speculations as to how they potentially will develop. What seems to be central in the production of virtual descriptions (virtual descriptions being a mode of lifting the forces similar to the ones found in Uccello´s painting into its abstracted, diagrammatic and generic mode) is the investigation, production and description of groupings, densities and configurations into direction and time-based forces. Time enters the picture on its most basic level since directionality implies movement. Movement introduces time-based processes.

Figure 41 Uccello´s Battle of San Romano: Imagined infill of frames in the movement of the lines. The yellow lines indicate the original positions of the pikes. The colouring of the different "frames" contributes to the illusion of a captured movement. Interpolation would create a continuous flowing motional form. This interpretation of virtual movement in the painting is based as much on the virtual movement of form itself as an interpretation of the moments before and after the moment of the picture,

Brian Massumi (Massumi, 1998) criticises a confusion of the virtual and digital technology. According to Massumi, the virtual appears in the sequencing and sampling of images rather than in their content or structure. This brings us back to Uccello's painting. The virtual dimension in the painting lies in its reading as one of many possible snapshots of an event. We can imagine the moments before and after the chosen snapshot. The picture is open towards both past and future. Massumi describes the role of the image in this sense:

> Images of the virtual make the virtual appear, not in their content or structure, but in fleeting, in their sequencing or sampling. The appearance of the virtual is in the twists and folds of content, as it moves from one sampled structure to another. It is in the ins and outs of imagistic content or structure. (Massumi, 1998)

Massumi claims that the single image is not able to represent or hold the virtual. I think Massumi is blurring the virtual when he detaches it from the content and especially from structure. I think it has much to do with both structure and content, as I argued in the analysis of The Battle of San Romano by Uccello. On the contrary, I believe the structure of the image holds the potential virtual movement and the promise of a sequence that is "existent due to power of possibility".

It seems unreasonable to exclude the single image from being able to produce the virtual. As already demonstrated by Uccello, an image can appear as open both to what preceded it and to its continuation. The movements in Uccello's pikes are real in a certain sense, even detached from semantic representation, though they do not physically move. These movements depict a possible

reality, simultaneously being a real feature of the painted canvas. The picture appears to represent a snapshot, a particular moment in a sequence that is open towards the past and the future. This relates to Massumi's conception of the virtual as bound to sequence. Massumi modifies himself later regarding the singular image:

> Since the virtual is in the ins and outs, the only way an image can approach it alone, with its own content and structure, is to twist and fold on itself, to multiply itself internally, knotting at a certain point. Doublings and foldings, punctualities rejoining encompassments, prospection buckling into retrospection, expanding contractions and contracting expanses. (Massumi, 1998)

This rather cryptic sentence is hard to understand unless we read further to where Massumi points at topological models as offering the best approach to understanding virtuality:

> This is to say that the virtual is best approached topologically. Topology is the science of self-varying deformation. A topological figure is defined as the continuous transformation of one geometrical figure into another..... Of course it is impossible actually to diagram every step in a topological transformation. Practically only selected stills can be presented. Once again, the need arises to superpose the sequencings. It is only in that superposition that the unity of the figure can be grasped as such, in one stroke... (:306)

But Massumi´s solution, to use superposition to deal with the implied problems of treating topological transformations in time, is not totally convincing. Superposition is one of several important techniques, each of which has limitations. Others are sequencing and video based real-time analysis. Arnheim points to Kretschmer claiming to use a similar method to Francis Galton's composite photographic technique when researching human types. Hundreds of images of similar types of people were superimposed. This was thought of as producing the most typical features of the type. Arnheim concludes:

> Actually, Galton's photos have shown that the results of such superposition are singularly unenlightening because the variations from rimen to specimen blur not only the atypical traits but the typical ones as well. (Arnheim, 1969)

Arnheim later points to the reason for failure of superposition as an analytical technique. The typicality of a structure lies in the relation between the elements and their dimensioning as much as in the elements themselves. This relation is blurred in superpositioning techniques. At least this is valid when

we are talking of a large number of samples to produce a statistically sound investigation. But this is not a problem when we look at topological transitions with only as many instances as allow a clear reading of each of them.

I think that Massumi argues too narrowly when he claims that the singular image can only capture the virtual if it "folds on itself" which, if I understand Massumi right, simply translates to superimposing.[79] Uccello showed that the virtual is as much a feature of structural relations and their inherent potential development, which does not necessarily have to be spelled out in more than one instance.

It is also hard to exclude non-topological formations from the realm of virtuality. Non-topological transformation, being discontinuity or the bringing together and establishing of relations between initially unrelated entities, is central to human perception and creativity, precisely because it creates the missing bridges between the separate entities.

Finally, I need to add a few (oppositional) remarks on current trends in architectural discourse. Very often a narrative becomes dominating and tends to seduce large groups in certain spheres. The result is that these narratives are then no longer questioned.

I would like to challenge the recent mantra that all entities in the world have to be regarded as dynamic. This is of course ultimately true and in many cases a very fruitful approach, but it contradicts our common sense of the nature of things. We are trapped in our human time-scale which naturally lets us regard certain things as fairly stable, like mountains and even buildings to a certain degree (both of course being results of formation processes). Even if we intend to design for change and according to the dynamics of real-life, we mostly end up with fairly still architectural constructs, industrial design products being a little more dynamic. The contemporary view of the world as all-dynamic has become a straight jacket in the design process and needs to be balanced. The point is that the time scale of buildings, and even more the time scale of a mountain range, is so large that everyday life still needs to form itself around given conditions. It may make sense to take into account the alteration of a building during its lifetime, but it makes no sense to plan according to geological time scale (yet). But where does that leave the virtual? I think there is no reason to leave out the notion of stillness from virtuality.

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[79] But to be fair, I am not really sure what Massumi means with this as well as his use of the term superimposing. One could imagine few instances or instances displayed side by side which would produce the effect of reading a topological transition.

Although the notion of virtuality is unclear and has several interpretations, it is regardless fruitful to detach it from the recent dependence on computer representation. The virtual may in this context point to a stage between material reality and its abstract diagrammatic organisation and in some cases it may depict potential development.

3.8.3. Analysing the virtual

To understand the virtual in detail so that we can utilise the design potential of an abstract virtual material we need to develop analysing strategies. The discovery of the emergent material is dependent on how we read and analyse it. The emergent material invites an inductive approach where we look for new phenomena and invent new categories rather than looking for recognition, association and categorisation related to the already known. If we bring our pre-established experience with us, and try to fit the material to a known world, we will be prevented from discovering the new. Therefore an inductive bottom-up analysis will be most beneficial.[80] I labelled this concept of analysis as "Virtual Phenomena" (Sevaldson, 1998) by which I mean looking for characteristic events that would not necessarily inspire an association for a design but that would suggest the structure of a possible event.

The analysis of virtual phenomena was first done in a small animation of several cursors along generated animation paths. The animations were the result of a long process of transforming information. Intersection lines from earlier geometries were used as animation paths for a series of experiments with cursors. The paths were generated from the intersection of several surfaces that originated from the colour displacement processes in 'Synthetic Landscape'[81] (See Figure 57 and Figure 58)

The cursors were animated along the paths within a fixed time frame. Long paths generated fast movements while cursors with short paths moved slowly. A number of different phenomena were discovered during the analysis of the animation. (Figure 42)

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[80] Again, the relations to Grounded Research are obvious.

[81] From the project "Synthetic Landscape" which was initiated by Johan Bettum OCEAN Oslo 1997. The relevant parts of the project will be treated in several places in this thesis.
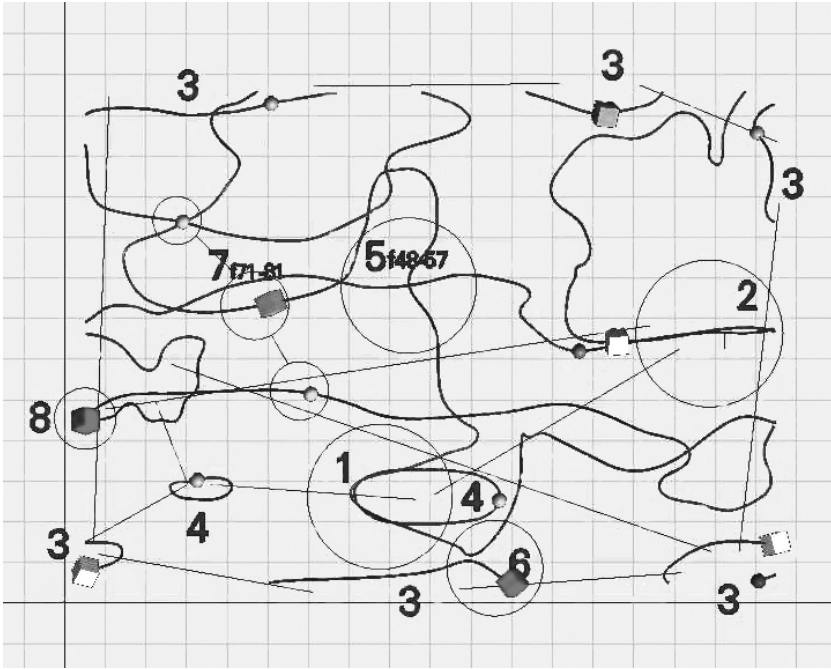
Figure 42 The field with the animation cursors and their paths. A number of phenomena are marked and numbered amongst them the later mentioned parallel phenomenon (number 7) and 'collision-follow-me' constituted by number 1, 4 and 6.

A simple example of a 'virtual phenomenon' is described below (Figure 43). Three moving cursors establish a spatial relation when they move in the same direction and in an approximately parallel formation. The coincident of time and space constitutes the virtual phenomenon. An event occurs when there is an outstanding relation established between the moving cursors.
This relation appears while the cursors move closer to each other or while they form relations because of their directionality, and it fades as they travel on. The intensity of closeness and directionality and hence the established relation is here indicated by scaling the cursors.
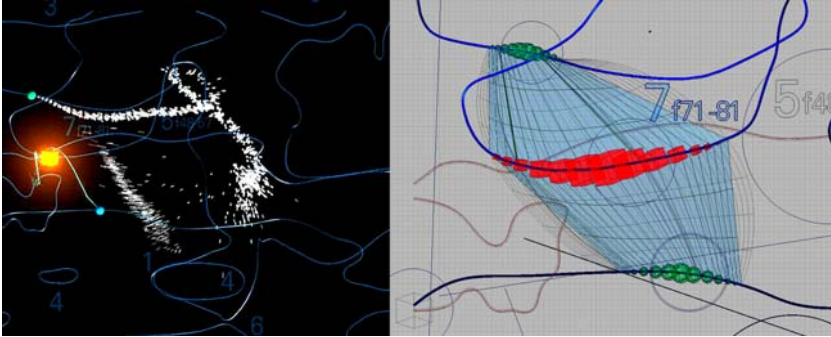
*Figure 43 The parallel phenomenon from above is here diagrammatically analyzed.
Three cursors share direction moving in a nearly parallel formation from the right to
the left (left). In the derived analysis (right) the play of forces depicted in the particle
system was disregarded. The parallel movement was illustrated by the superimposing
of several corresponding positions of the three cursors. By connecting these positions
a network of lines was created. The result is a 'relation surface' developed between
the three cursors. (BS 1998)*

The image below (Figure 44) shows a more complex event that is formed by
multiple phenomena operating together in a limited time frame. The
phenomenon was called "Collision/Follow-Me". The image shows a time
collapse, with multiple frames shown on one image. The yellow cursor
moves from the right to the left and via a curve to the top of the frame while
the orange cursor moves very slowly from the left to the right. They collide
in the lower right corner of the frame. The green cursor moves in an elliptical
orbit and flies in formation with the yellow cursor for a moment. This creates
a complex relation between three dynamic objects which is established only
because of their motion.

"Collision/Follow-Me" was later used for some sketches for the entrance
design of a hotel lobby to inform the movement and timed sequence of how
guests would enter the lobby and interact with the reception. It was a partly
successful attempt to translate not only the formal organisation but also the
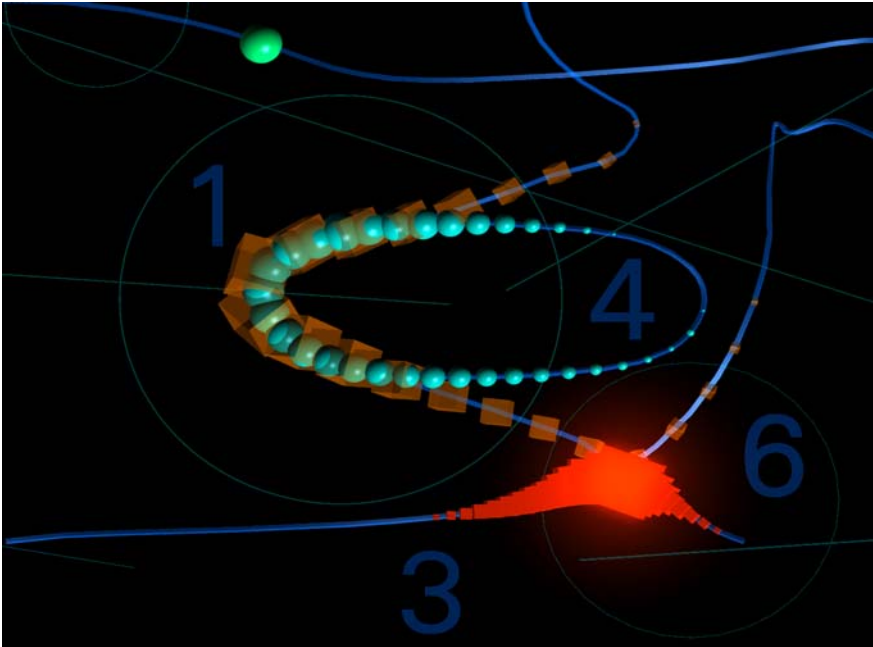structural and motion-based relations into a design solution.

Figure 44 "Collision/Follow-me" (From the project Synthetic Landscape, 1998 Animations and analyses by Birger Sevaldson)
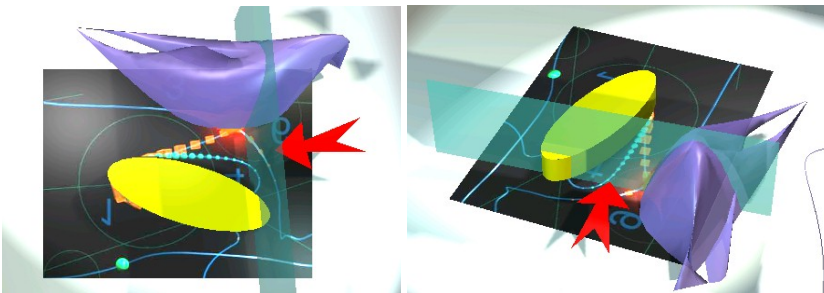

Figure 45 A sketch for a hotel lobby where the spatial event from 'collision-follow-me' informs the way customers approach the hotel reception (yellow). (BS 1998)

Though these sketches were never developed further, it demonstrated how a virtual phenomenon can provide source material for design processes concerned with the design of events rather than objects or spaces.

Another study of virtual phenomena investigates detailed behaviours and relations between animated cursors. (See Figure 46) The tilting and rotation and direction of the cursors are illustrated by means of sail-like shapes. Spatial phenomena like clustering and separations, direction and densities are identified by circles. Tendencies are given by arrows. These techniques could be useful for the diagrammatic analysis of both virtually generated phenomena or of real-life behaviour in complex systems.
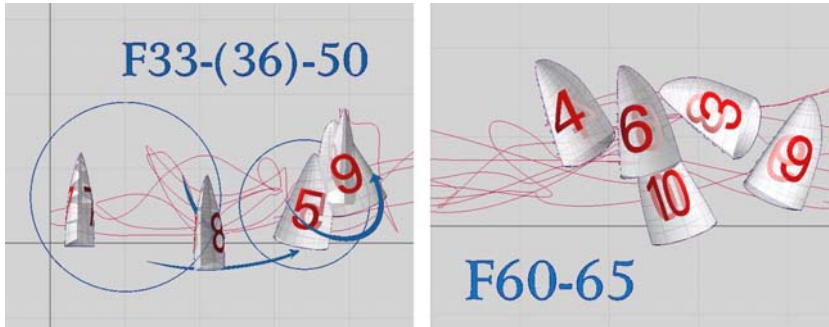

Figure 46 Virtual phenomena. Detailed study of cursor behaviors. (BS 1998)

3.9. VISUAL THINKING (DIAGRAMS AND VISUAL THINKING)

When analysing "the virtual" we have worked with the visual material in a way that is based on reasoning around visual elements. The virtual phenomena described above are found on the basis of relations between elements in space. These relations are configurations that we can analyse on the basis of perception and thinking. We will now look more closely at a phenomenon that exists between cognition and perception: visual thinking.

3.9.1. Visual Thinking and Abstraction.

The conception of visual thinking in this thesis is largely based on the thinking of Rudolf Arnheim. Arnheim was professor of the Psychology of Art at Harvard University. Arnheim had connections with Gestalt psychology but did not regard himself as a Gestalt Psychologist. In a conversation with Paul Rand, Arnheim stated:

> All that Gestalt psychology is saying is: in whatever science..   .. you have to deal with the structure of the whole (Kleinman and Duzer, 1997)

Arnheim described the principles of visual thinking in far more detail than any earlier attempt. One of the most important points in Rudolf Arnheim's influential book 'Visual Thinking' is that perception and cognition are seamlessly integrated and are not to be separated from each other.[82] The basis of perception is the abstractive understanding of structural features, which also is thought to be the beginning of cognition (Arnheim, 1969). Arnheim claims that the process of analysis and the production of cognitive concepts begins with perception. Perception and cognition (analysis and the formation of concepts) should not be separated. In the chapter "Shapes are Concepts" he writes:

> In the perception of shape lie the beginnings of concept formation. The perception of shape is the grasping of structural features found in, or imposed upon, the stimulus material. Only rarely does this material conform exactly to the shapes it acquires in perception. The full moon is indeed round, to the best of our viewing powers. But most of the things we see as round do not embody roundness literally; they are mere approximations. (Arnheim, 1969)

The projection of abstract geometric concepts like roundness is an inherent part of perception. Arnheim states that abstraction is a main element of visual thinking. Perception is a dynamic phenomenon since the relation between the observer and object constantly changes. The projection of objects changes according to the position of the observer. This dynamic altering of the observed triggers abstractive generalisation:

> First the projective distortions not only **permit** the discovery of the prototype inherent within them; they **call** for it actively. Projection produces not a static deviation but a dynamic distortion, which is perceived as animated by a tension directed towards the simpler form from which it deviates. (Arnheim, 1969)

Abstraction is the ability to perceive the most typical but also relevant features of an object. [83] Since relevance is not computable, and probably will not be in the near future, a quantitative or algorithmic approach is not applicable. (Sevaldson, 1999a) This is also demonstrated as mentioned

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[82] See page 13 - 17 for a detailed argumentation for a view on cognition that includes perception and also unconscious or less conscious modes of cognition. (Arnheim, 1969) Other sources that have been useful in this chapter are: (Arnheim, 1969, Akner-Koler, 1994, Beardon, 1999a, Beardon, 1999b, Goldschmidt, 1994, McCullough, 1996)

[83] Arnheim uses two whole chapters to clear out any misunderstanding of what abstraction is, amongst them the popular conception of abstract as opposite to concrete. Abstraction is used here in the same way as used by Arnheim.

earlier by Arnheim's reference to Galton's composite photographic technique. Referring to the qualitative nature of abstraction Arnheim describes it as an art:

> The art of drawing essentials from a given kind of entity can apply only to organized wholes, in which some features hold key positions while others are secondary or accidental. (Arnheim, 1969)

Visual thinking is in fact an everyday part of perception and cognition but for the sake of this thesis we need to frame this broad and complex theme in relation to visual thinking in the design process. Visual thinking in design means to visualise structures and their organisation and the handling of topological relations (Arnheim, 1969), be it a concrete design problem or a formal structural (abstract and organisational or physical structure like building structure) or sculptural construct or possibility. Visual thinking also means to develop or solve these structures through new revised versions.

3.9.2. A heuristic process

Most designers practice a circular (heuristic) process of externalised visualisation and internal analysis.[84] It seems that careful and accurate visualisation (visual thinking) is the only way for most designers to solve complex design problems. This suggests that visual thinking is not necessarily a quick and spontaneous nor intuitive process. It can be tedious, analytical and laborious. The two modes, visualisation and analysis, may be conducted simultaneously or they can be separated in time.

Modes of visual thinking connected to the development of skills through practice are heuristic processes. This implies that at the beginning of a process the visual thinker, for example a designer, is not able to completely overlook the end of the process. It implies a step into the unknown. It implies that to a certain degree the visual material operates on an abstract and generic level and that the material slowly becomes more concrete through generative processes.

3.9.3. Visual thinking, skills and tacit knowledge

A process based on visual thinking implies solving problems or developing potential designs informed by the means of a visual material. It means to modify that visual material or to derive and develop new visual material. Visual thinking is learning through doing or cognition through practice. Most human activities are only possible to learn through practical exercise. This goes for all physical activities from learning to walking or skiing, playing an

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[84] The heuristic method: a procedure for searching out an *unknown* goal by incremental exploration. (Bullock et al., 1988)

instrument or drawing a picture. But this, to a certain degree, also goes for intellectual activities like writing a paper. Physical activities can be modified through verbal input but dexterity cannot be achieved without experimenting through practical trial and error and in the end rehearsal. This means that one has to practice and analyse (reflect) simultaneously and that both practice and analysis are developed through mutual influence and correction.
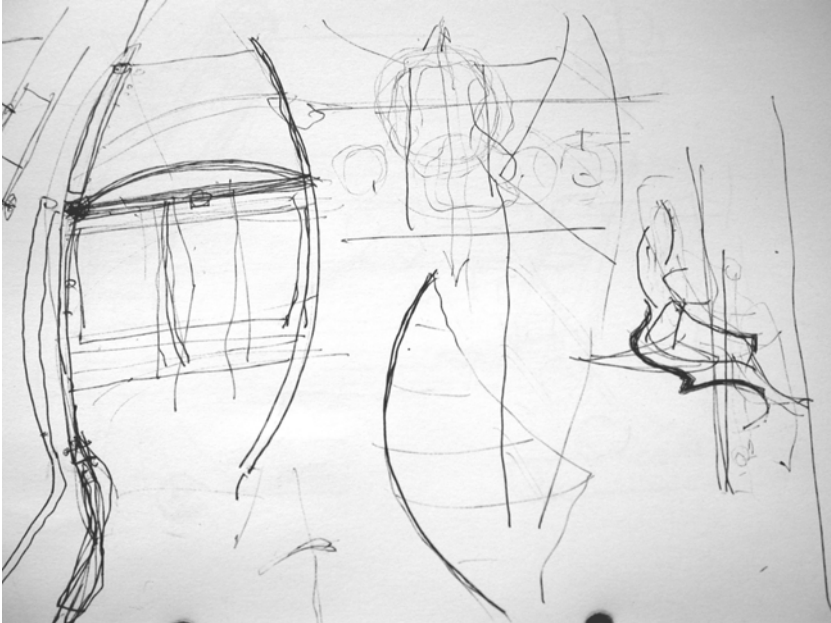
3.9.4. Media for visual thinking

In early sketching phases many designers still use traditional drawing tools. Early sketches often look rudimentary and abstract, which indicates that this way of sketching involves visual thinking. The sketches only partially represent something that is completed by the sketcher's imagination and reasoning. The process is often spiral, iterative as thoughts and ideas are evaluated through sketching, which again informs new thoughts. But the myth of the pencil as a totally intuitive or spontaneous tool must be questioned. Though we do not need to solve technicalities while using a pen, (as opposed to working with a computer), it is not an easy tool to master. Many years of training are required, and still the level of accuracy is limited. Sooner or later one is forced to leave the free initial sketching style and use more accurate techniques such as technical drawing, where CAD has already proved its advantages. In any design process the stage of accurate documentation is also an integrated part of the creative process. Such a phase will normally speed up the process and give it new direction.[85]

Traditional sketching techniques in early design stages are used to support intuitive visual thinking. Early design sketches are often suggestive, blurred, inaccurate, schematic, and often only understood in the intended way by the person who produced them.

 Other people will interpret the sketches differently, which is both a disadvantage and an advantage in a collaborative design process. Diverse interpretations become a problem if we are trying to achieve a consolidation and consensus on which we can base decision-making. In these cases we want as accurate and unambiguous material as possible. But in the phases where things are still very much open, unclear sketches that are open for interpretation are an advantage.

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[85] A "trick" that I often encouraged my students to use when they were stuck, is to draw and construct the product as if it was finished. This helps to get into the detail phase of the design process.

Figure 47 Early design sketches work as tools for visual thinking. They appear partly diagrammatic and partly as early manifestations of design ideas. Such sketches are hard to interpret for others than the artist. Sketches from the installation AGORA: Boundary Conditions, Oslo Central Station 2002. (Birger Sevaldson)

Reinterpretation by the different members in a collaborative design team can produce new and unexpected solutions. Often a teamwork-based design process can increase production speed at such early sketching stages because the sketches are reinterpreted in various ways other than those intended by the drawer. A sketchy drawing preserves an openness that helps to reach creative results. The potential of a hand-made graphical sketch lies in its inaccuracy and openness. This means it is open to several reinterpretations. It has an interesting structure on a diagrammatic level, because it is open to complex adaptation.

The sketches together with visual thinking in a mode of dialogue contribute to a generative collaborative design process. Interpretation is central in generative design processes.

Keeping in mind what was said before about interpretation of generative material this is a point where there are only small principle differences between traditional techniques and generative creative computer use. A pen drawing is limited when it comes to complexity. Most often it has no colour

depth; it is only in grey shades or monochrome lines. By adding colour, the hand sketch can carry more information, but it tends to be structurally homogenous since its main component is often the line and more rarely involves shading.

Compared with the pen drawing, the computer-generated sketch has some disadvantages but many more advantages. Usually a computer sketch is more laborious to produce, while a hand sketch is quicker and can be done more easily over the table while communicating with other people. However, the computer sketch can be altered much more quickly and can handle much more complex information. Layering can separate the diverse information sets in a complex scene, which makes visual analysis possible even in very complex systems. By displaying one layer at the time or by altering the transparency of the layers we can change the visual emphasis. Structural complexity is easily increased in computer-generated images.

The computer sketch is also much more dynamic since it is easily manipulated. From traditional drawing classes we know the trick of observing a sketch through a mirror or upside down to "clear the perception" and get a fresh view. The computer equipped with graphical manipulation software can add a lot to this. A simple PhotoShop filter like inversing an image is very efficient in triggering new interpretations. Blurring is very well suited to identifying global structural features, which often are confused by smaller details. By increasing contrasts we can more easily read the most important fields of intensity since less intense areas are tuned out. All this helps us to read the image in a structural way. The diagrammatic features of the image become clearer.

In the example above (Figure 48) we have returned to Uccello. First a step of inversion creates an alienation to the picture. Content becomes distant. Then a step of blurring removes all details so that only the overall organisation of colours and lightness remain. In the last step I have used a contrasting filter to simplify further and make the main areas of the picture very clear.

Figure 48 Visual manipulation of Uccello´s The Battle of San Marino. Top right: inverse of original. This simple filter induces a rereading of the picture. Bottom left: A Gaussian blur filter is applied. It diffuses all details and leaves only the big variations. Bottom right: The blurred image is contrasted which draws a very simplified diagram of the main fields and their organisation in Uccello´s composition.

The question now is whether we can see some of the dynamic movement in this way, similar to what we saw in the analysis of the pikes. Did Uccello use the grades of lightness in the overall composition to contribute to the dynamic of the picture. The answer is of course "yes". The central dark field is "leaning" over and totally dominates the small dark field on the right. Looking at the un-manipulated image, we can see how Uccello used the background as part of a wave-like movement overwhelming whatever should be in the lower right corner. This analysis could be expanded further to include the drawing of lines throughout the image.

Blurring is one of several techniques that help us to analyse an image.
It is listed as one of the conceptual tools in Peter Eisenman's list of tools in 'Diagram Diaries' (Eisenman, 1999a).

The easy manipulation of the parameters implies that the computer sketch can induce time-based design much more easily than the traditional hand sketch.

Time-based tools for dynamic visual thinking

Software with timelines can be used in visual design processes that include dynamic developments over time. These software applications include animation software like Maya or 3DStudio, video editing software like Adobe Premiere and After Effects, and motion graphics software like Flash. Sound software and other time-based software are also of use.

In the perspective of visual thinking, time-based analysis is especially interesting. The structure and nature of changes and movements can be analysed in depth. Techniques include time scaling (slow motion or fast motion), time section (still frames) time loops, reversing, collapsing (superimposing) and scratching. Combined with graphic filtering as described above in, e.g. After Effects, these tools provide new insight into processes that might otherwise be hard to analyse because of their speed or slowness or their complexity. Time-based patterns are revealed and clarified in a way that provides a new reading of the material. These tools are very useful for the investigation of real-life video. (See Figure 49)
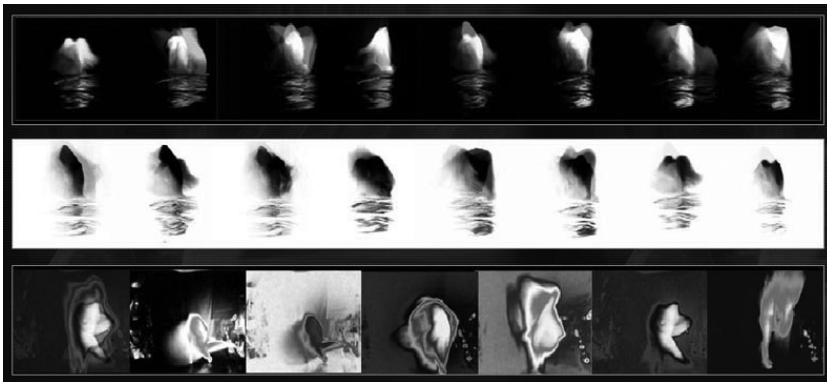
Figure 49 An example of the use of video software to generate a visual analyses of a recorded motion sequence of a student using textile as motion envelop (top row). The video is clarified by inversing and contrasting the original(middle row) Finally certain frames are developed into generative diagrams of a potential motion space through the extensive use of graphic filters (bottom row) From the project Designing Time, Students

3.10. DIAGRAMMATIC THINKING

What is a diagram? A simple and inclusive definition is:

Diagramming is any technique which reinforces the display of certain features of an observation at the cost of others.[86]

This definition embraces both the more traditional conception of the diagram as a designed graphic display of quantitative information and the graphic display of qualitative structural organisation of patterns and behaviours. It is not always possible to distinguish the quantitative from the qualitative. Visualisation of the amount of data is regarded as quantitative. But when we start to juxtapose several streams of information patterns, relations appear in the graphic visualisation. It is difficult or impossible to describe these patterns, tendencies and relations in quantitative terms and the description must be qualitative and visual. (Figure 50)

In the image below (Figure 51) we return to the former blurring and contrasting analysis of the picture by Uccello (Figure 48). It demonstrates that the central aspect of diagramming, the display of certain features at the cost of others, is also relevant in qualitative analyses. Each of the four instances show certain structures and the relation between them and obscures others. The upper left and lower right image each separate the most extreme fields in the image. The upper left isolates the darkest areas while the lower right isolates the lightest areas of the original picture. (Note that the graphic work started with an inversion of the original image). The other two images are positions in between the two extremes.

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[86] Peter Eisenman states in: However, the diagram is not a scientific instrument that gives a precise reading; rather it allows a given range of readings at the same time that it obscures others. (Eisenman, 1999a) More about Diagrams History of the diagram: Kwinter>Göthe (form-formation) (Kwinter, 1999) Tufte provides an overview of descriptive diagramming techniques (Tufte, 1983).
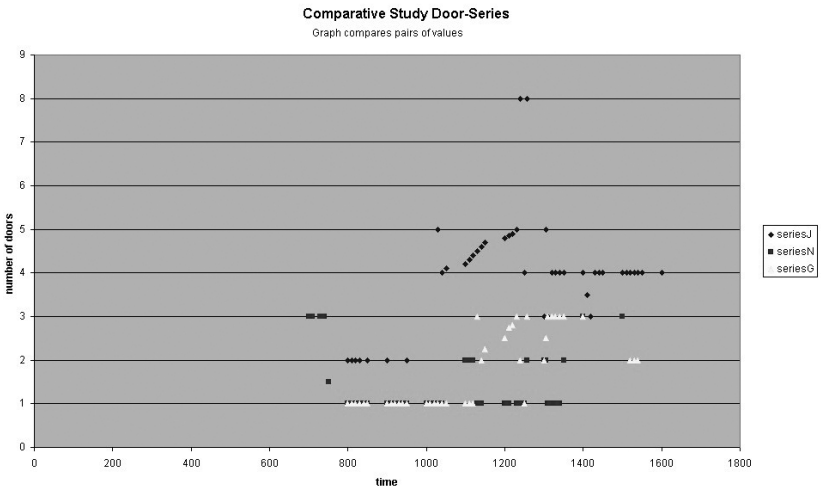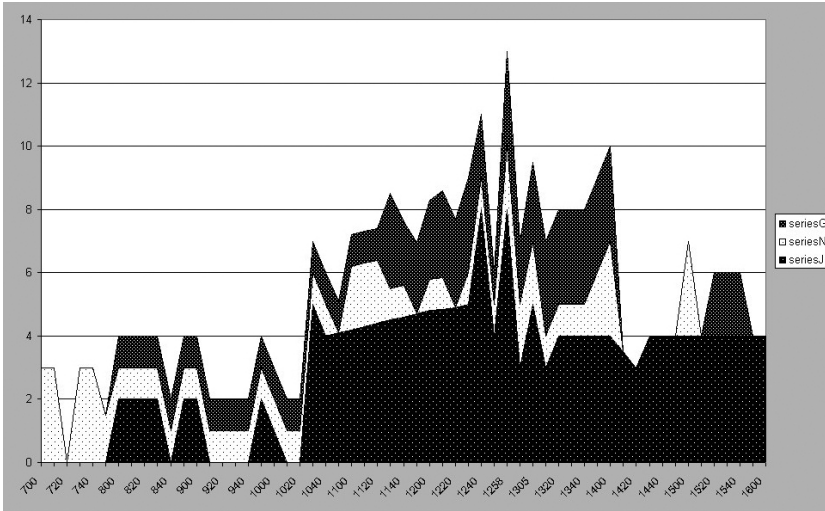
Figure 50 The display of quantitative information. Both diagrams display the same data. The way the data is displayed visualises qualitative aspects of the patterns and relations hidden in the data. (Tidsrom)
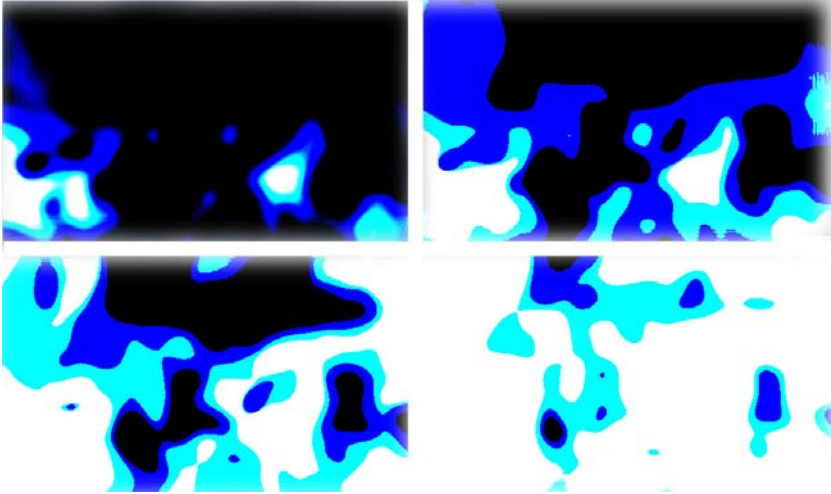
Figure 51 Manipulating Uccello´s "Battle of San Romano"
By manipulating the brightness that corresponds with the contrasting thresholds, we
can produce a long range of different diagrams each of which reinforces specific
aspects of Uccello´s composition. The image shows four instances with varied
brightness parameter from the darkest (upper left) to the brightest (lower right). The
upper left and lower right diagrams show the most intense spots while the other two
images show the overall organisation including the virtual movement and direction in
the composition

The interesting aspect here is that the different instances show quite different
aspects of the image. Keep in mind that they are all derivations from the
original and hence diagram real features of the original. No data has been
added or removed; it is only tweaked according to certain thresholds. The
upper left and lower right extremes no longer clearly show the movement in
the composition. Instead they show the most intense spots in the image.
Simply by altering the parameters of the filters we are able to uncover
structurally diverse aspects of the graphical data.

According to Arnheim perception and cognition comprise a seamless
integrated process, (Arnheim, 1969). Visualisation and the following analysis
are the results of perception and cognition where the diagram plays a central
role in the analysis. Each one of these elements of the perception process
makes us able to perceive some limited aspects of reality. Combining these
different modes we will achieve the kind of holistic width and a depth that
we need in a design process. The direct observation of the object itself only
reveals limited aspects of the object's nature. To grasp the object's position,
relations and performance in the surrounding fields we need to understand its
virtual ins and outs (as Massumi puts it (Massumi, 1998)) or its degree of

openness and interface, its abstracted representation and its diagrammatic field of relational forces, all equally real and representing parts of a holistic understanding. This implies that a diagram is real in the sense that it mimics, describes or produces real features, configurations and processes, though they are not always directly perceivable.

Arnheim points to gestures as a demonstration of how abstraction is inherent in human nature. (Arnheim, 1969) Though he does not directly refer to diagrams in this context, it is easy to read gestures on a diagrammatic level. Especially gestures which describe processes and events (time-based transformations) are strikingly well-suited to diagramming the **qualitative** aspects of the event. A particularly informative example is to be found in the conducting of an orchestra, where the dynamics of the composition are visualised in a diagrammatic way by the body and sign language of the conductor.[87] In another example, Arnheim points to a 'prototype of drawing' that is closely related to gestures:

> ...those diagrammatic scribbles drawn on the blackboard by teachers and lecturers in order to describe constellations of one kind or another- physical or social, psychological or purely logical (Arnheim, 1969).

These drawings represent a link between gestures and the designed diagram which indicates that diagrammatical thinking is a natural thing.

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[87] A big source on multidisciplinary research on gestures is to be found on the website The Nonverbal Dictionary of Gestures, Signs and Body Language. (Givens, 2004)

3.10.1. Descriptive diagrams

Visualisation has long been an important aspect when dealing with complexity. Construction drawings are needed to obtain control over all the elements in complicated engineering design. Geographical maps are needed to navigate. Graphs and diagrams are needed to understand proportions and patterns between different parameters in trade and politics. Visual analyses are used to understand phenomena in scientific visualisation.


Figure 52 Why do we use maps instead of aerial photos when navigating? The maps leave out all the unnecessary details and add additional crucial information. In the middle, a map showing ownership of property, which is a socially constructed feature and not a feature of the physical landscape. The right-hand diagram is a map for nautical navigation that provides information about the depth of the seabed that is only perceivable with the assistance of instruments. Recalling the definition of diagram: maps are diagrams.

In their simplest form, diagrams are visual aids to understanding relations and structures in assembled systems. Diagramming makes it possible to grasp the whole of a complex situation. Complex systems of relations would be impossible to grasp without diagrams.

The bubble diagram has been widespread as a tool to map relations between elements. But these types of diagrams are very limited. They only establish that there is a relation, normally they do not include any descriptions of these relations. Somol refers to Eisenman and Alexander when he points to the shift in diagramming from merely mapping relations to describing the qualitative aspects of relations and how they would unfold over time. (Somol, 1999) Computer technology has contributed to the rethinking of the diagram as it presents new tools that include dynamic development of processes.

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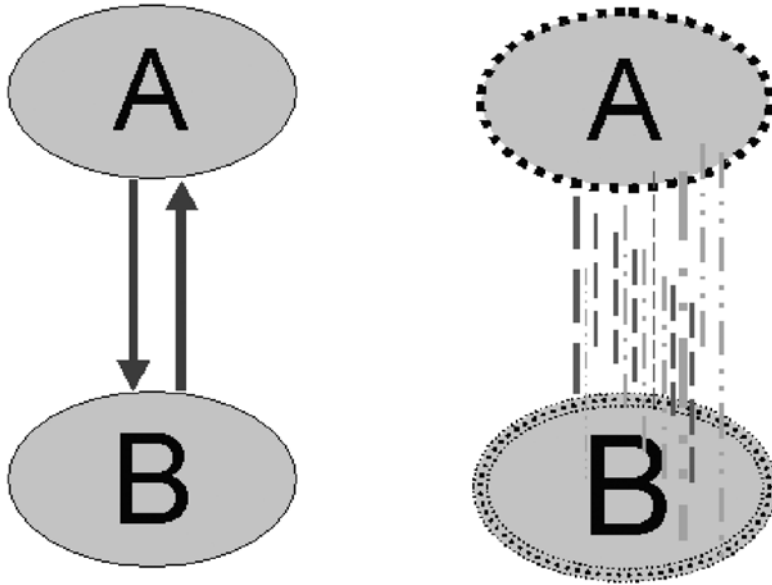
Figure 53 A traditional bubble diagram only establishes that there is a relation between A and B. New diagramming techniques tend to include a qualitative rendering of e.g. the relations and border conditions and how they would develop over a given time span.
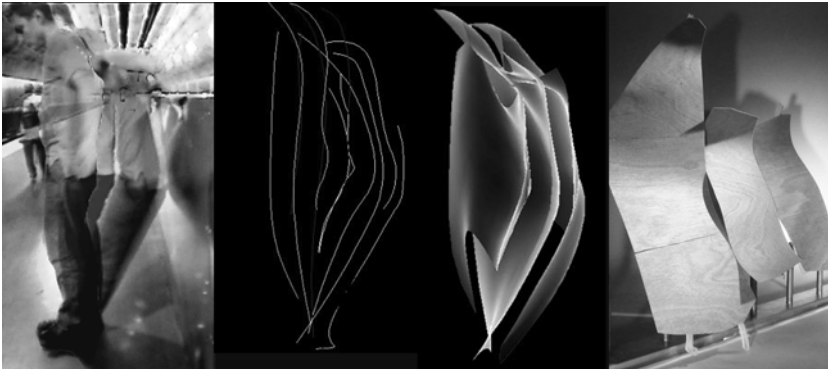
Figure 54 Video footage of staged typical movements used as generative material for the design of a leaning furniture. ("Conceptual Design Project" Oslo School of Architecture, Birger Sevaldson 2000. Group1, Lars Kløve Bjerke, Jens Andreas Pettersen)

3.10.2. Generative diagrams

Descriptive diagrams describe phenomena. Generative diagrams are devices that are used to design objects and spaces. Generative diagrams produce phenomena.

 In a design process we are, to a larger degree, free to interpret and code the data in any way we wish. The designer's means of control include interpretation, selection and monitoring of parameters. Throughout the whole process, aesthetic concerns are important. In addition the choice of source material is vital to the result. The source material is often used to implement global and holistic design intentions.

If we understand the initial hand sketch as the graphical seed of the design process, where shape, structures and relations between elements are more important than semantics, it is a short step to realise that computers are even better suited to generate and simulate such relational systems. We can initiate the process and the computer simulates how the relations will develop over time. The initial sketch or source material, whether computer-generated or handmade, is in such a case not merely descriptive. It can be abstract, suggestive, imaginative, speculative and intuitive. We sense a certain virtual quality of a spatial organisation, a pattern of behaviour or the performance of a system. These sketches are generative devices to develop certain features or forms we are interested in. They are our main tools in a creative process. The computer technology has induced a rethinking of these devices. There is little radically new in this but the generative work on the computer asks for a higher level of abstraction, translation and interpretation, a more intense involvement with diagramming and a partial departure from associative visualisation and composition. The diagram is central in this as a generative tool. In a design process we ambulate between the different tools and techniques. These shifts normally alter the direction of the process and often contribute to introduce new perspectives and approaches.
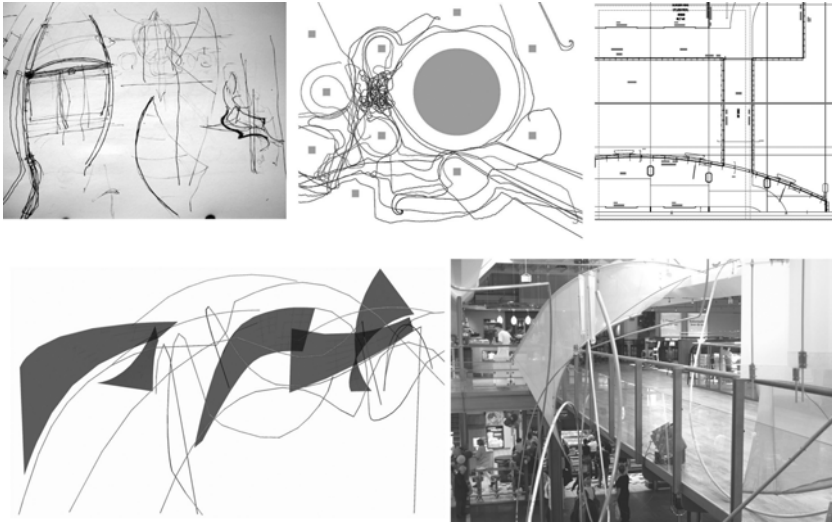
Figure 55 One and the same process contains many modes of generative, descriptive and representative visualisations. Top left: a hand sketch indicating and developing concepts for the organisation of spatial constructs. Middle top: a generative animation based on a flocking algorithm was used as a source material for the design. Top Right: normal construction drawing of the site. These are to be regarded as diagrammatic according to the definition used in this thesis. Bottom left: 3D-model of the installation. Bottom right: Final installation. (From AGORA: Boundary Conditions 2002)

The colour graft

In a hybrid process where many different techniques and media are involved, the initial sketch or source material for a generative diagrammatic process could still be hand drawn but in a completely different way. The first sketch and source material for the long-term research project "Synthetic Landscape" was a "Colour Graft". The colour graft is a special type of source material. While a traditional sketching process tends to be explicit, causing a process of development that is based on decision-making, a "Colour Graft" is the source material for a process that develops smoothly. Such processes are evolutionary and develop through "versioning" a theme that has been treated especially in one issue of 'Architectural Design' (Pasquarelli, 2002).

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Figure 56 The "Colour Graft". Source material for a long series of experiments.
Hand drawing by Johan Bettum. The information derived from this source material
evolved through several projects: Synthetic Landscape 1997, Synthetic Pavilion 1999
and Ambient Amplifiers 2000.

 "Colour Graft" is a term invented by Jeffrey Kipnis. The term refers to the
process of "grafting" colour coded source material onto a specific site
(Kipnis, 1993). Michael Hensel (who was a student of Kipnis and who
credits the following quote to Kipnis) describes the concept of grafting:

> Referring to Kipnis, the term grafting is borrowed from biology and
> more specifically botany. The idea of 'grafting' is to mediate between
> an existing context and a new organisation that is to be implemented
> within this context. The existing and the new 'tissue' show no distinct
> seam, contrary to common master-planning based on completely
> clearing a context by erasing the existing fabric (tabula rasa) and
> implementing a new one that is clearly distinct from its surrounding.
> This notion is directly related to the notion of the 'smooth' discussed
> by Eisenman. While the term 'grafting' may not be widely in use it is

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nevertheless the case that the connected critique of 'tabula rasa' and the treatment of 'seams' within the urban fabric has not only persisted, but also informed many contemporary projects.

Michael Hensel continues:

> The intention of the colour graft is to smoothen hard border conditions, both between the existing and the new and the various systems that make up the graft. One of the inspirations of Kipnis were Jasper John's 'Cross-hatch' paintings in which in fact the layering escapes discernability, an effect termed 'a new middle-ground', which defies decomposability into fore-, middle- and background. The cross-hatches are blended through different levels of transparency, which involves the white areas of the canvas, which turn out to be white hatches. Non-decomposability is thus a characteristic that works both in the planar and the depth axes. The technique and pose of the 'colour-graft' is directly informed by John's technique and has the same intentions. The smooth relation to the context is added by Kipnis as an urbanistic argument against extensive forms of organisation such as the 'grid'. (Hensel, 2005)

The concept was an important inspiration in the development of the digital techniques in OCEAN NORTH but it was not always understood in the way Kipnis introduced it. For some of us (including myself) it took on the role more as a generic source material similar to how electronic artists such as Natasha Barrett use the term *source material*.

Computer graphics help to add colour depth to the graphical source material. This means that if we split the graphics into its colour components through colour filtering, one and the same visual data set can contain several channels of information. Since these channels come from the same graphics they are related to each other. Therefore they can be seamlessly re-integrated into each other. Colour fields also easily can be codified into spatial structures, through displacement mapping.

Grafting the initial graphic information into real-life data
One strategy we developed in OCEAN NORTH to build the generic ability to adapt into the program is to render the diagram, and therefore the program, as a system of at least two interacting and interweaved sub-systems. In contrast to the functionalistic approach to adaptation which involves changing the program, the generic space, the dynamic diagram and the program have a high level of detail and articulation. The hypothesis is that this should provide the ability to adapt both on macro and micro levels.

Interweaving and interaction are the starting points of the architectural idea of continuously differentiated space. This continuous space with an implied multiple system mechanics is achieved by relating at minimum one system to another, generic diagram to program, colour graft to topology. The term grafting implies that one information-set is grafted into another, not through simple juxtaposition, but through negotiating the two systems. Grafting differs from collage in as much as the colour graft and the real-life data are investigated for co-relations and "quasi-congruencies", interactions and continuities, while the collage produces a simple superimposition of differences, contrasts and detachedness. While the relations produced in the collage are fragmented and have to be established on a subjective level, the relations in a grafting process are articulated structurally as they deal with relations on an objective diagrammatic level. We can identify the relations in the diagram, point them out, categorise them and discuss them as phenomena.

Colour grafting can be applied to many stages and different areas of the design process. Colour grafts can inform structural and diagrammatic levels of program space, social space, topology, form and structure. The initial information is to be transformed into the final design through finding situations where the two or more information sets interrelate and where they can be negotiated. Individual interpretation, redefinition and redesign through selection and modification are important elements in these transformation processes.

In the case of "Synthetic Landscape" the colour graft was first applied to the site by simply mapping it onto a map of the area, the Tøyen Park, an urban park in the east of Oslo. From this starting point a long process was initiated, where the site and the information from the colour graft where processed both in 2D and 3D interpretations.

The abstract elements of the graphic space of the 'graft' undergo a series of graphic transformations, while being at the same time increasingly understood as definite architectural or urban items and conditions.

The site map and colour graft were first translated into spatial data. A site model was built and the colour graft was split into several colour channels that were used for displacement mapping of surfaces, a simple way of translating the image data into spatial surfaces.
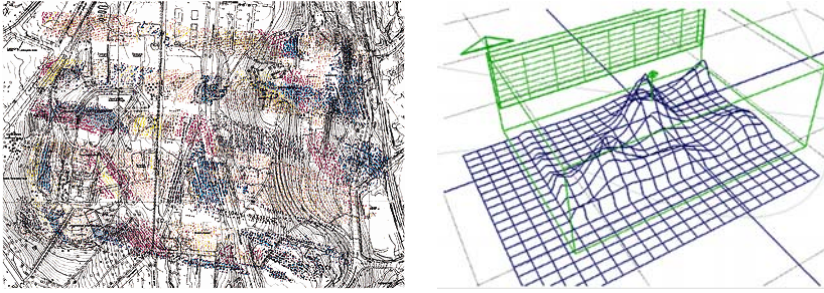
Figure 57 Left: The colour graft is mapped onto the site of the case study. Right: The colour-graft was split into six colour channels (Photoshop) which where used as displacement information to deform surfaces. Peaks depict high colour intensity while valleys correspond to low colour intensity. These surfaces were wrapped to a topographical model of the site. This produces surfaces that contain both the generative information and site-specific (topographic) information. (Johan Bettum & Kim Baumann Larsen)

From there an evolutionary design process was initiated which entailed the careful production of large numbers of versions, following an internal logic of incremental steps according to a development path along all of the different colour channels that had been separated from the colour graft.

3.10.3. Versioning

This process produces a large amount of material in an endless line of versions. It is an open-ended process where what is shown appears to be only a segment of a much longer process that started long ago and that finishes in a far future. It never reaches a final goal, because there is no end in such a process; it could continue indefinitely.

The computer enables the frequent registering and storing of stages in a process. It is very easy to redesign an earlier product or to reverse engineer what others have done. RP-technology enables the continuous output of physical models. This has radically altered the conditions for design work from what they were before the computer entered the design office. When correcting a drawing or adjusting a sketch model the original version was lost if specific efforts were not made to copy the original. Further advantage can be gained from the computer by setting it up to automatically produce a large number of versions to ease decision making. In industrial design these techniques could range from arranging different parts of an assembly, reusing standard parts, altering parameters and relations to testing a long range of possible materials and colour combinations. This again is so successful that it is not only a feature of any product development process but it has also made

its way into the customisation of products on a large scale. In design offices, it became a natural part of design work to produce and reuse a large number of versions. When two formal solutions were at hand it was easy to investigate all variations in-between by changing parameters. By using morphing algorithms, this process can even be automated and we have thus reached a generative design process.

The production of a large number of versions provides the designer with a better basis for decision making and hence a greater amount of control. In generative design we can say that control is moved from one part of the process to another. Hands-on control with the singular design version is surrendered in favour of control gained by testing a much greater amount of possibilities.

Manuel DeLanda refers to *population thinking* in his article about genetic algorithms. (DeLanda, 2002) Although I distinguish between genetic algorithms and generative design computing, I think that to a certain degree this is also relevant for the more free process, based on other mathematics than the simulation of genetic code and more explicit modelling, for example in animation software. Population thinking considers the population, not the individual as the basis for the development of form. In my work this has been true only to a certain degree. Most often I select certain instances for further development and the steps are radical and not "genetically smooth".

The material in Synthetic Landscape was developed further over several years.[88] There is nothing artificial about such a process. Though we act as if we were the designers of a final product, we know that what we do is connected to what we have done before, and that each finalised project contains potential for future development. The shift is partly conceptual and partly technological. Conceptually the shift is towards a more negotiation-oriented and system-oriented design philosophy. From this follows a rejection of the perfect form and the right solution and an adaptation of the notion of flexibility and performance. The emphasis on open-ended processes is driven by digital technology and the ever-swelling hard disks where we tend to store every little move in our lives. (Blogging being only the latest symptom.) Every instance of our design process, every little move can be stored. At this moment of writing, my disks can store 50 GB, which in a few years will be regarded as nothing. My disks are old and there is forgotten information there in the cellars and the lofts of the deep folder structures. Information is doubled, it is layered and versioned over and over again. Information deposits are waiting to be re-found (for example through data-mining).

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[88] I will return to this project later.

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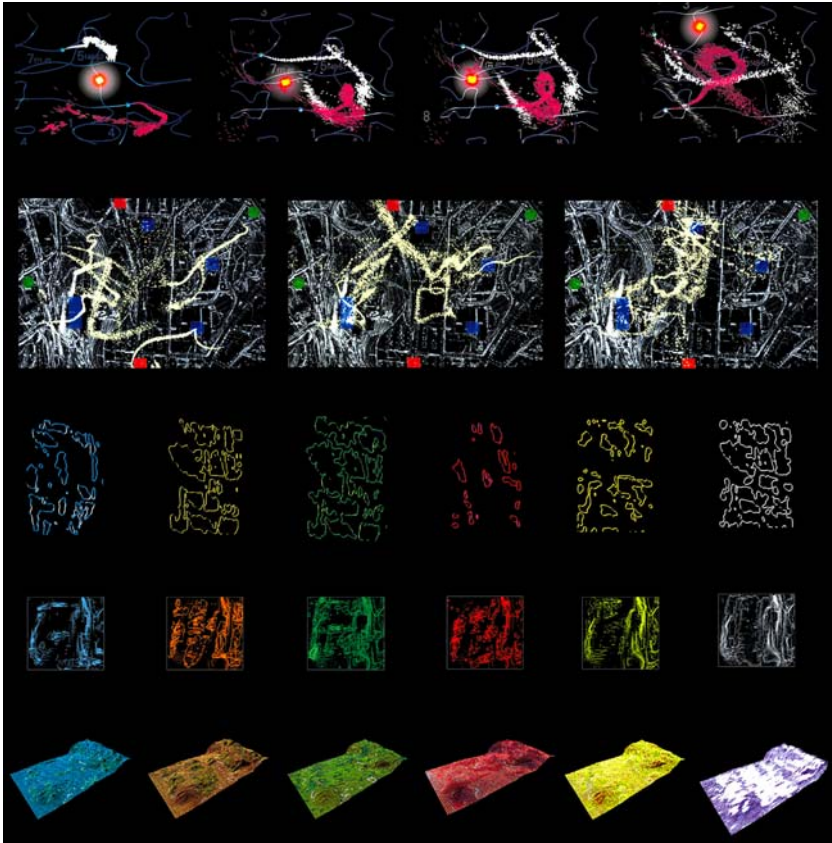
Figure 58 Versioning: The process of evolving the generative material. Starting from bottom to top: displacement mapping paired with landscape topography; intensity mapping onto landscape; intersection-lines between landscape and intensity maps; particle animations derived from intersection lines. (work by Johan Bettum, Kim Baumann Larsen and Birger Sevaldson 1997)

Versioning is a phenomenon from long ago. But with the digital age it has become a major principle of production. Software is not finished at its release or at any following version. It never finishes. It either dies or theoretically it could go on forever.

The generative processes of versioning live their own life parallel to the reality they engage. They are not entirely driven by the variables of real-life but are not entirely detached from them either. They are not entirely under control but also not entirely out of control. Geometries and information may migrate from one scale to another or travel to another application and site. The outputs are not finished products, rather they are unfinished because they

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always contain a past and a present, the virtual ins and outs (also found in Uccello´s painting). The products do not present an idea of 'the finished' as in the idea of Louis Kahn; that we need to find out "what a building wants to be". This notion is replaced with a notion of finding out "what the process wants to be".

I look at my data deposits sometimes with distance and wondering, rediscovering, finding material, finding opportunities and new connections and "bends" in the process.

Figure 59 In the deep deposits of my hard disks, amongst hundreds of versions I will find the instances that stand out. (From the World Centre for Human Concerns animation series).

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3.10.4. Finding

Pablo Picasso once stated that he was not creating, he was finding.

The processes I describe are partly self driven (emergent). They produce material slightly out of our designer control. In this material we *find* the instances we need. Finding is the function of desire and the function of inspiration (the desire and suffering Braham asked for (Braham, 2000)). From finding comes our subjective creative response.

I started to develop finding strategies early in 1996, when I realised the potential of the virtual 3D space and thought that this should be explored further. The main tool for this exploration was the VORB workshops.

VORB[89] is a series of workshops at Oslo School of Architecture that started in 1997, initiated and organised by the author. VORB stands *for "Virtuelle Objekter, Rom og Bevegelser"* (Virtual Objects, Spaces and Movements). The VORB project is thought of as both a teaching project and a research tool for practice-based research. The workshops were all tentative and explorative. The idea was that difficult steps in the development of digital design could be investigated in depth and much faster in this way than I could do on my own.

VORB 1 was a pilot study where early ideas were tested. The concept of the workshop was initially quite vague. From the project description we can read:

> The aim of the project is to explore the possibilities of the 3D application in total creative freedom. How can the designer use the virtual 3D space? What are the characteristics of VR compared to real-life space, and what can we do in VR which we can not do in real space? [90]

The first workshop was an unfocused and general investigation, where the students were told to design a freely defined object or space in 3D software. The only restriction was that this object or space should be non-figurative, and that the use of traditional drawing tools was prohibited. The intention was to do an initial scan of the virtual space and its possibilities and potential. No generic concepts or distinct techniques were developed at that stage.

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[89] http://www.aho.no/staff/bs/3d/vorb/
[90] See project description at http://www.aho.no/staff/bs/3D/vorb/oppgavev1.html (Translated by the author.)

As a pilot study, VORB1 was very useful. It helped to develop the ideas for VORB as an explorative environment. It was a necessary start for the first steps into unknown territory. Because of its unfocused nature, VORB1 gave useful background information and experience.[91] Although we did not use the term *finding* at this stage, this was a formulated *finding strategy*.

Five students did complete their project. All students worked with objects rather than spaces. A possible explanation is that most of them were industrial design students. Although one student was an architecture student, his project was object oriented as well. Another common trend was that all of the students worked with four dimensions, movements and animations.

 Successive VORB workshops developed from the generic initial approach towards more distinct and defined concepts, and at the same time from the abstract to the concrete, from space via architecture to product. The project description from VORB3 illustrates this development towards more specific modelling techniques:

> The students were required to find a graphical material that would serve as a starting point for the project. The graphics were analysed and the students, divided into four groups, used the graphics to inform 3D spatial models. Parallel model processes were conducted in both digital and physical form.[92]

The students were given "finding instructions". The graphic material should be non-figurative, complex and structurally interesting. The images were regarded as abstract spatial information, *colour space*. This term refers to the depth of the image both in relation to the potential variation and layering of structures in the image but also to the colour depth which was exploited in separation and recoding processes later. The structural organisation of the colour space should be diverse, detailed and provide for variations both on a macro and micro-level. The criteria were:

- A high degree of variation in the overall structural organisation: How rich and varied is the colour space on a macro level?

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[91] Jorgensen describes several explorative strategies, like using questionnaires as a fishing net, and to execute unfocused observations (Jorgensen, 1989). Also Fettermann mentions similar processes in ethnographic work talking off "informal interviews" "open-ended questions" and the process of "crystallisation"(Fettermann, 1989). See also Glaser and Strauss. (Glaser and Strauss, 1967). (For a more general and elaborate discussion see book1) Such techniques are especially useful in design research as we enter complex and unknown areas and VORB1 is to be seen in such a context.

[92] http://www.ifid.aho.no/bs/vorb

- A high degree of variation of local structures: Does the image provide articulated and varied patterns and structures when you zoom in?
- A high degree of variation in the patterning on both macro and micro-level: What patterns does the image contain? Look for variations in densities, groupings, singularities, directions and border conditions.
- A wide colour space: How many colours does the image contain? (The colour space could be altered and expanded as shown in Figure 60).

This is a training exercise for the students to distinguish potentially promising source material from source material with less potential to be developed into diversified and nuanced output.

An example from VORB3 shows how a student developed a 3D space from a found material. Here the found image was used as an intensity map. The image was filtered to split it into separate information layers. Also the image was developed further via graphic filtering. Finally the different layers were used to inform a surface space where colour intensity was mapped to the height of a surface deformation.
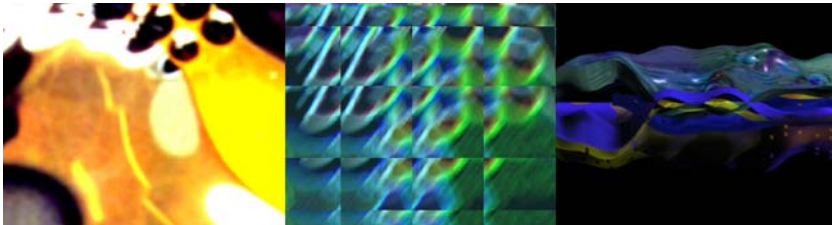
Figure 60 From the VORB3 Workshop: A found source material to the left is transformed in PhotoShop (middle) and used to develop a three-dimensional space (right) (Gergely Agoston 1998)

These graphical sources for information of both form and program are called generative diagrams. In contrast to descriptive diagrams, which help us to understand structural principles of existing systems and situations, generative diagrams help us to generate possible structural, organisational and formal principles on a generic level.[93] It is possible to find elements that are similar

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[93] Generative diagrams are discussed in Greg Lynn's article on Ben van Berkel. Forms of Expression: The Proto-functional Potential of Diagrams in Architectural

to generative diagrams in many design processes when structural variations in possible solutions are investigated or when formal principles are developed. In fact the borders between a normal sketch and a generative diagram are fluid. A normal sketch in an early stage of the design process is a simplification of the formal, organisational and structural problems. Often these sketches have diagrammatic qualities. The difference is that the sketch and the generative diagram are fed by different sources and that they reach for different ends. The manual sketch is a direct reflection of a cognitive process of interactive visual reasoning or intuitive response. It normally seeks to reduce the possible solutions and to reach a stage where one solution is chosen. The generative diagram is generated from a process where the input parameters and the set up are prepared in advance. It generates a wide range of possibilities and a complex and layered output that enriches the process (inclusive process).

Diagrammatic reading of such early design material is useful to understand and develop it further. Examples are often found when designers plan according to sequences or time-based events like the sequential use of an object or environments.
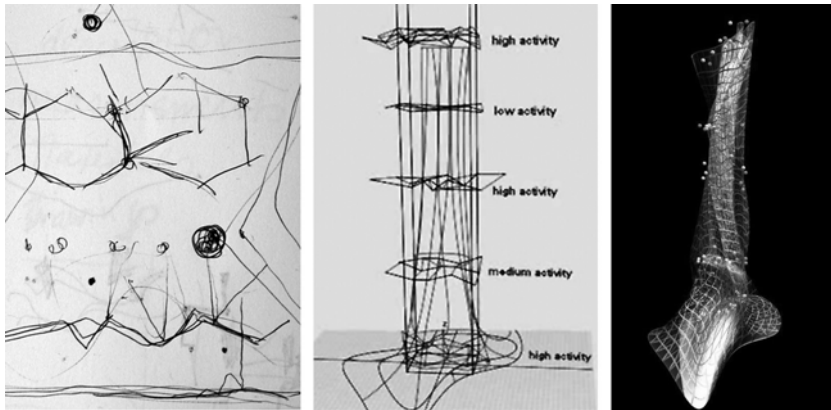
Figure 61 The concept for a generative dynamic diagramming machine was developed with traditional hand sketches. Experimental development of a design process for a high-rise study. (Birger Sevaldson 1999)

Design, El Croquis no.72/73 (Lynn) See also Peter Eisenmans Diagram Diaries and Any Diagram Work (Cynthia C. Davidson, 1998)

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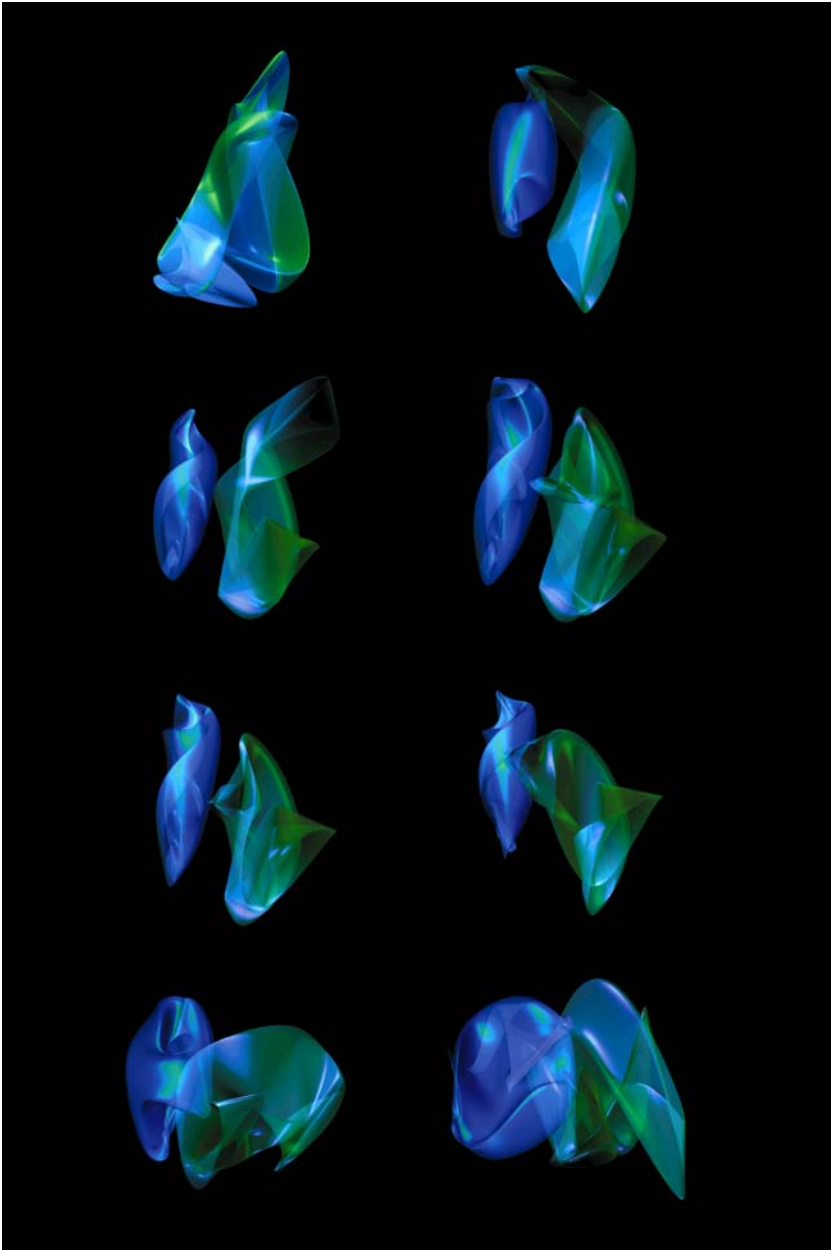
Figure 62 The beautiful product of a design process where the computerized emergence and the human designer are equally important. (a-drift 1999)

3.10.5. Translation and interpretation

Material produced from the generative diagram is generic to a certain degree. Although it can contain some start conditions, values and geometrical features as well as variables representing real-life forces, it is only tied to these real-life conditions to a certain degree. The output can be totally abstract, only representing potential spatial and temporal structures, relations and possible material organisation. Ali Rahim states that the dynamic diagram is both conceptual and material. (Rahim, 2000). We could add that it could be social, climatic, economic, bionomic or other categories. This approach was first suggested by Johan Bettum and Michael Hensel in their article about "Channelling Systems" (Bettum and Hensel, 2000). Basically, the generative material was in this case used as a spatial mapping device for the different programs. Bettum and Hensel's strategy reflects the problem of the role of the architect when we depart from *"the humbled architect.. .. as just another variable in the diagramming"* (Braham, 2000) Bettum and Hensel address this issue by suggesting a strategy of synergy between the analytical and generative:

> An alternative to deterministic closed systems and freely evolving, open systems would be a process that establishes a dynamic relationship between the determining force of design with the emergent qualities of evolving systems. Such a strategy would potentially draw upon synergetic effects between designed and evolved conditions within the urban matrix. Therefore a design technique must seek to fuse analytical and generative processes and allow for exchange mechanisms between designed and evolving conditions to take place. (Bettum and Hensel, 2000)

A design strategy that seeks to fuse analysis and the generative will continually be engaged in interpretation. The generative material is contextualised, merged and negotiated in terms of a specific program and context. The dynamic diagram serves as a device for reading the system concerned. It serves as a device for the projection of intentions, as a filter for articulation and a device to incorporate the unforeseen.

Bettum and Hensel write that:

> The dynamics of contemporary urban conditions mean that analysis must be an ongoing process that constantly incorporates information on changing conditions. (Bettum and Hensel, 2000)

They argue that a planning process based on fixed and limited information obstructs the transpiring analysis of a dynamic design process. The generative material, migrating from a long process represented in ever-changing versions, is detached from a fixed interpretation. Because the

material moves from one scale to another, from one context to another, it is frequently interpreted again and again. Secondly they argue that a process based on fixed information reaches a complete design solution denying the incorporation of potential responses to the inevitable shifting conditions of the future.

Human sense (meaning, culture) is projected onto the material through interpretation which gives the generative material content and makes it ready for reuse.[94] Although interpretation of a given material is increasingly important compared to a "traditional" (internal self-centric) design process, the designer is by no means removed from being a creative and productive individual. However, the production process is altered. The designer is in phases forced into a state of disinterest and detachment, operating the parameters of the processes rather than personally being the process engine. [95] This detachment ensures a distance that enables an open eye for findings ("Finding eye").

In order to utilise the initially generic material, it is on the one hand investigated for its structural inherent organisation[96], on the other it is related to external information or use, be it form or program. A simple and direct associative and metaphorically based projection might be most obvious. But there is a high risk that such an approach will lead us into non-productive banalities. We need to extract processable material, which is open-ended either because it is not determent (complex, blurred, unclear, open to several interpretations) and/or because it operates on a generic - diagrammatical level. Diagrammatic thinking may open up diverse modes of interpretation, which helps to avoid a direct and banal translation of the generative material.[97]

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[94] Though meaning is already present since the designer introduces a priory an intention-driven selection through the choice of technology, design of process and selection of parameters.

[95] Disinterest and personal detachment to the process of creativity connects on one side to ethics of science (CUDOS) on the other to certain movements in art. This gives this mode of work its fascinating potential. See also Eisenman: *My use of the diagram proposed a different rationale, one that could be both more logical and more involved with a process of architecture somewhat distant from the design process of the traditional author-architect.* (Eisenman, 1999a)

[96] Structural in its literal sense as the organisation and layout of formal issues like framework, outline, distribution, direction, density, border conditions and similar features of form in general.

[97] The diagram is in that sense an engine for data reduction since it clarifies and emphasises certain readings of the material while disguising others.

Translation techniques

The generative diagram provides an indirect method of deriving form or informing formal issues. A direct approach would also be possible. The emergent visual material could be used as a formal template. (This approach will be discussed later.) The attraction of an indirect approach to deriving form is being able to treat form on its diagrammatic level. In this way we seek to develop formal structures and principles more than form itself. The abstract elements of the generative diagram are developed through several steps of spatial and diagrammatical transformations. In this process the diagram is slowly interpreted as conditions, forces and relations and in later developments as sites, constructs and objects. Form is a generated result from a complex process.

I use the term *scaffold* for a specific stage between the abstract diagram and form. Scaffolds are mediation devices between the abstract generative diagram and the resulting construct or template for the final design. The reason for this is to maintain flexibility towards the implementation of the visual material. We need to process, negotiate and develop the material which will slowly develop. The grafting and negotiation techniques used to process programmatic information are relevant to formal issues as well. We have no wish to replace an existing dogma with a new one, but we wish to bring new elements and considerations into the design process. We wish to add something to design culture not replace what exists. Our goal is to maintain the freedom and initiative of current design to break and redefine rules. Therefore the process of developing rules and their implementation is important.

The diagram's role in the process of giving form is to give resistance to the obvious, which is central in any creative process. Here I think it is necessary to refer again to Eisenman's description of the diagram as a device for overcoming the motivated where the diagram acts as a resistant agent to *"...separate form from function, form from meaning and architect from the process of design."* (Eisenman, 1999a). In the same text Eisenman reminds us that we cannot totally escape the motivated in architecture.

Along the path from source material to final design the material is processed with diverse computer-based or physical modelling techniques. Translation of the visual material from one process to another will trigger reinterpretation of the material. New ways of understanding the material will initiate changes and departures in the process. The project does not develop along a planned route but follows paths that are revealed while the work is under progress.

In particular, the translation from virtual to physical or vice versa evokes a process of rethinking all aspects of the design. Physical construction immediately becomes an issue and the solving of the model will be one step

towards the final construction. Finding methods to build a complex virtual model in real materials is challenging and forces us to analyse the virtual model and exactly understand its geometry. This geometry is then developed and refined towards a built construct. The generative diagrams rarely inform buildings directly, they need to be further interpreted and processed to derive constructs that are possible to build. We need to interpret the structural nature of the model to represent it in another media. The strictness of the match between the generative diagram and the built interpretation varies a lot. In some cases this relation is very loose.

In the project Synthetic Pavilion we developed these issues and started to distinguish between fairly tight relations and very loose relations. (Figure 64) In the next step, the Ambient Amplifyer project[98] we started to use the term scaffold for generative elements that rested in-between the diagrammatic and the design template[99]. The scaffold, though supporting final form and thus related to final form is at the same time free to possess its own structure and appearance.

A process that moves from source material to final design in several steps was first tested in the Synthetic Pavilion; a spatial particle animation was used as a design template (see Figure 63).
The cross sections were traced creating an outline of vector-based lines. From this I developed a detailed design study of a section of the pavilion that was finally produced in an RP-model (see Figure 66).

Synthetic Pavilion.
Experimental building design 1999.
Birger Sevaldson, Johan Bettum, Kim B. Larsen, Gergely Agoston et.al.

A further development of the scaffolding device could be to make the scaffold structurally dependent on final form so it is (re-) generated simultaneously throughout the development and manipulation of final form. This would develop the scaffold into a more advanced negotiation device that would also have generative potential.

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[98] Birger Sevaldson and Phu Duong
[99] Stan Allan refers to certain structures serve as scaffolds for events unanticipated by the architect. (Allen, 1999b)
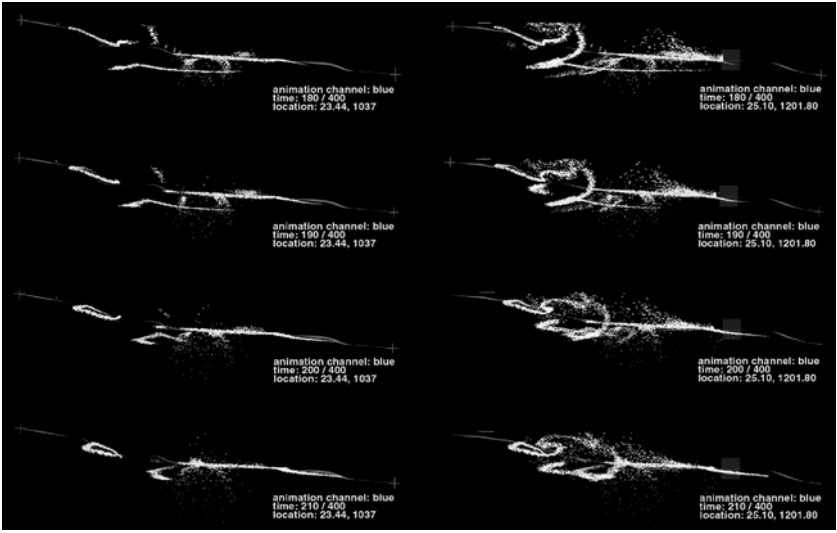
Figure 63 Particle animation for the Synthetic Pavilion. The image shows eight cross section through the particle-space that were used as design templates.
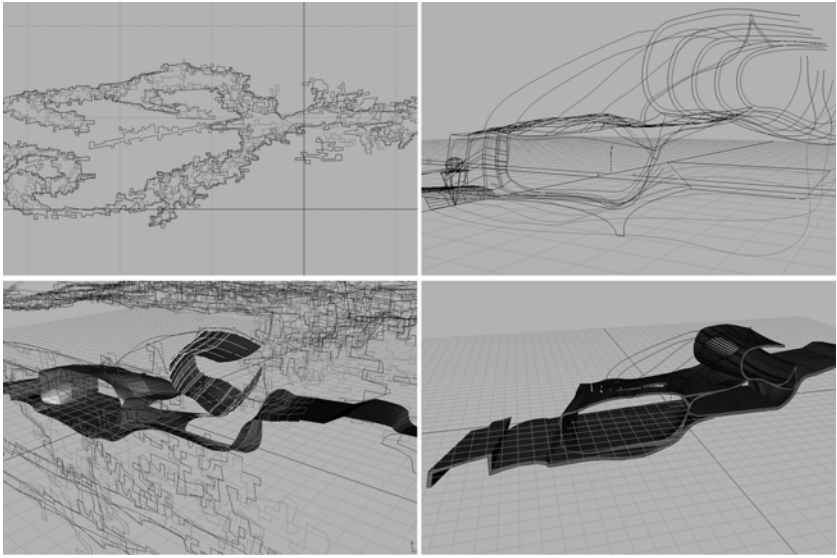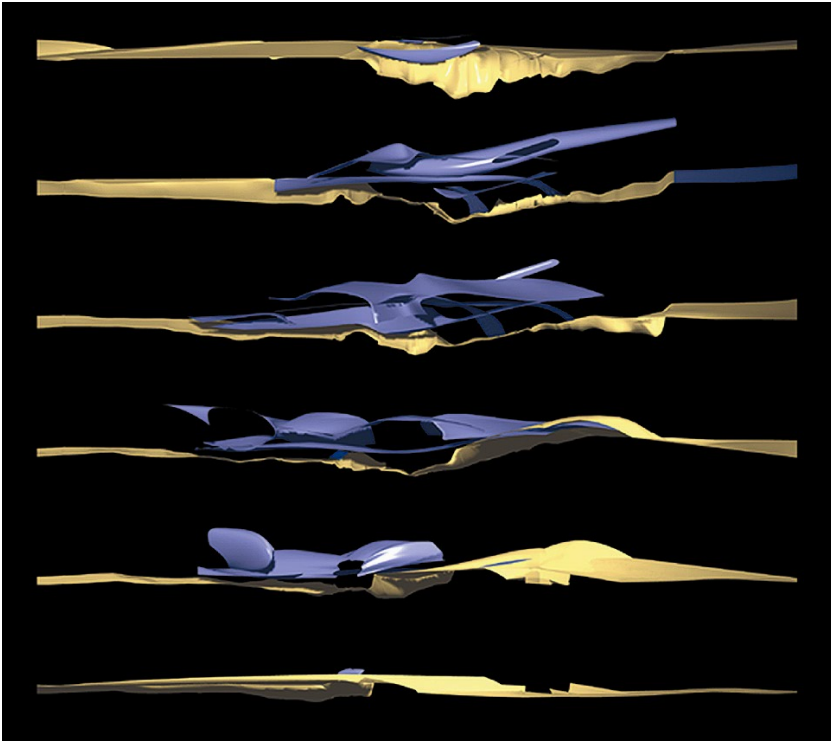

Figure 64 Development of a section of the Synthetic Pavilion. Top left: Traced cross section of particles. Top right: first construction lines that were drawn along the traced vector lines. Bottom left: first sketch of the section. Bottom right: final design of the section

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Figure 65 The resulting model of the Synthetic Pavilion was very complex. Despite techniques for investigation of the geometries like the here shown sectioning of the digital model, it was first when we produced a rapid prototyping model that we fully could appreciate the geometry of the pavilion. (Rendering by Gergely Agoston)
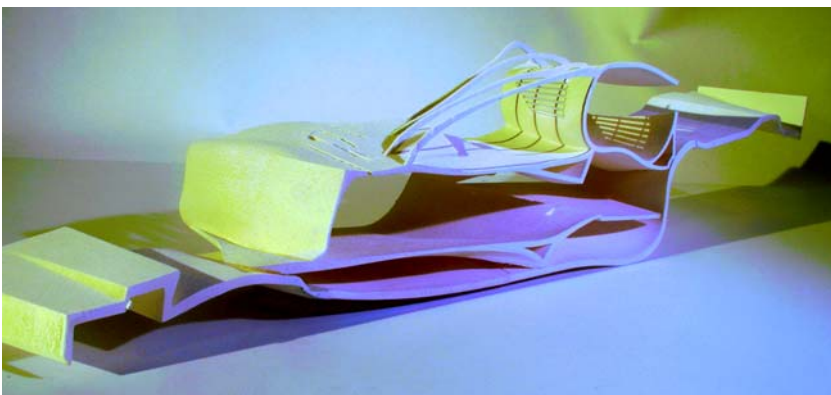
Figure 66 Final RP-model of a section through the model. See also Figure 89.

The difference between template and scaffold lies in the degree of directness in the translation of the source material into form. We will return to templating and scaffolding later.

The strangeness of the generative material appears to be an advantage. In traditional processes the known building technology and its limitations are already present in early concept sketches. This is another example of the designer's schemata, and is normally an advantage to the experienced professional, but which can also get in the way of innovation. The generative material challenges what we know. It forces us to implement the consciously guided and maintained translation processes, where the generative material, the design intentions and visions and the limits of what is technically possible are negotiated.
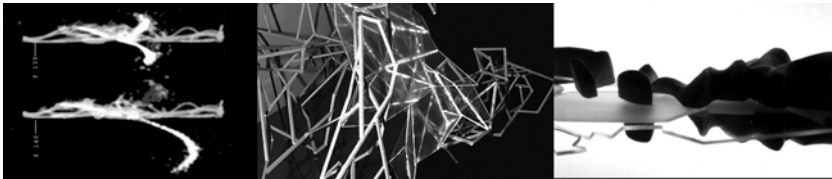
Figure 67 In a workshop in Finland (Vaasa 1997) the students were given the task of building physical models from the digital source material on the left. Despite the fact that the different analyses were comparable, the same source material resulted in very different results depending on the chosen material and technique.

All processing of these models entail using data reduction techniques. The complex scaffolds are simplified into their various essential elements (In other cases these simplified reduced models can be used to instigate new processes that again will increase the amount of information.)

A built physical abstract model will also represent an intermediate stage between the virtual and abstract and the final result. The intermediate model can represent both performative organisation and the structural organisation of space. It is also useful as a stage on the way towards built structure. Through physical modelling we rehearse ways of transforming the initial formal information into built form.

The same principles developed for the digital generative diagram were tested in physical models (1999 at the Architectural Association School of Architecture, Diploma Unit Four and the Oslo School of Architecture, Institute of Industrial Design.) These experiments indicate a return to physical analogue modelling, where the physical model appears as generative mechanical diagrams in combination with digital models.

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The digital techniques are here translated and reinvented in another medium. This reinvention tweaks the use of dynamic generative diagrams because of its altered possibilities and limitations.[100]

Parallel modelling

In the VORB 4 workshop[101], translation between physical and digital media was explored (Bugge et al., 1999). A three dimensional generative diagram was developed in parallel as a physical and digital model. The experiment demonstrated the difference in potential between the two media.
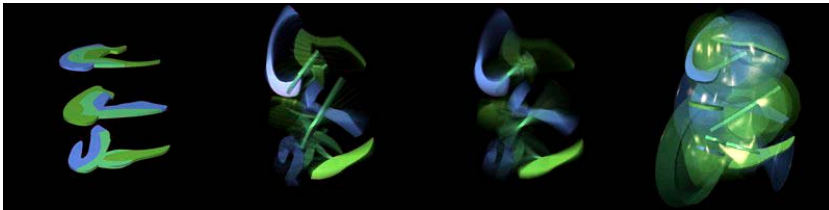
Figure 68 Digital model of a dynamic diagrammatic space. (VORB 4, students: Andreas Bugge, Inger-Elisabeth Løvstad, Christian Abry, Ulrich Behr, Mathias Arnlinder 1999)

The digital model has the advantage of being easy to construct and it gives a great degree of freedom to alter the parameters, e.g. the axes of rotation are easily manipulated (Figure 68). Building and modifying the physical model are much more time consuming. Furthermore, the digital model permits storage of many steps and versions and spatial mapping of certain events. The physical model also prevents or restricts some movements whereas a digital model is not restricted by collisions between geometries.

The physical model has an advantage because it is so easily accessible and it will provide a much more instant perception of the space. (See Figure 70) The restrictions mentioned above might also be an advantage. The inclusion of materiality and explicit spatiality could be regarded as information and possible opportunity, since one is still not yet 'problem solving', but 'opportunity finding'.

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[100] OCEAN projects like Jyväskylä, Chamberworks and workshops: Building Dynamic Relations (Helsinki Vaasa 1997) Dynamic Relations in Design (Oslo 1998) Vorb3 (1998) Vorb4 (1999)

[101] VORB 4 was lead by the author. Johan Bettum was co-teaching.
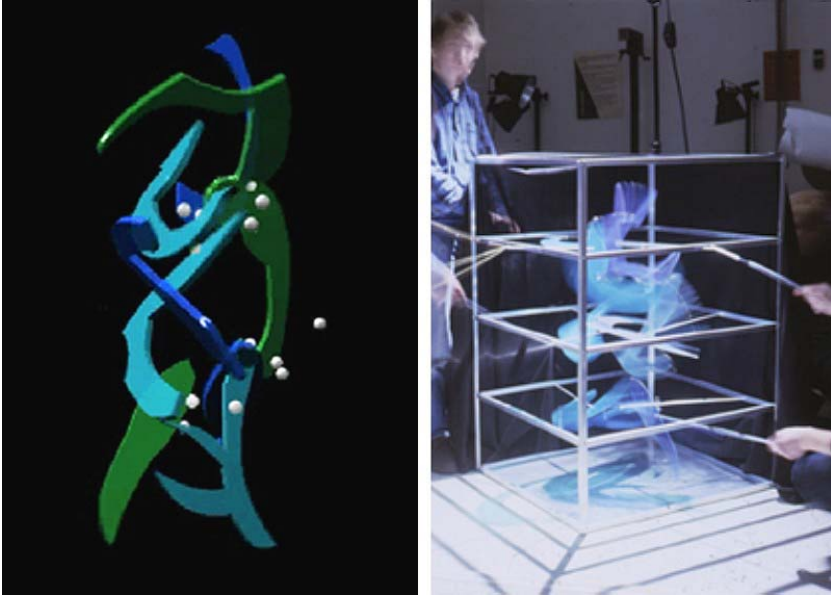
Figure 69 In the digital model it is possible to register spatial events in a more accurate and convenient way than is possible in the physical model. Here all collision points between the shapes are registered. The physical dynamic generative diagram was operated by several people simultaneously and according to certain rules that were agreed upon.
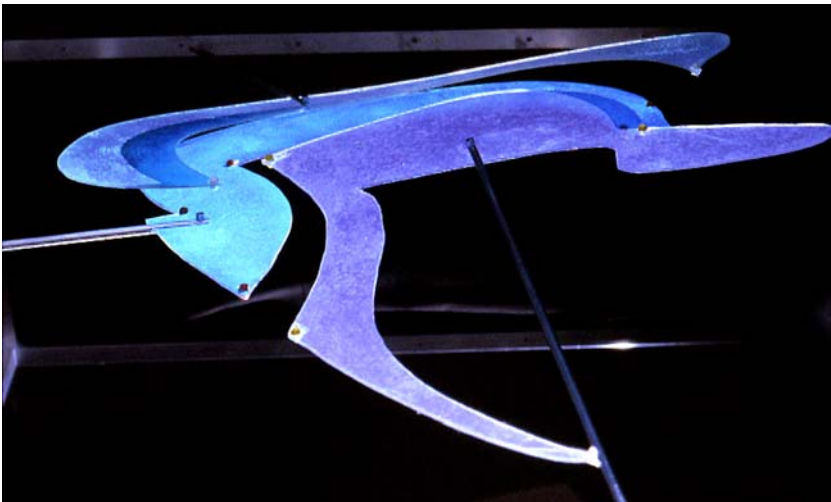
Figure 70 The model was constructed along three sets of axes in three planes. Each axis rotated a shape that was derived from a given source material.

A physical model will create a smooth development towards a built construction and includes material technologies and restraints. The physical model in this sample was recorded with different photographing techniques in particular the use of slow shutter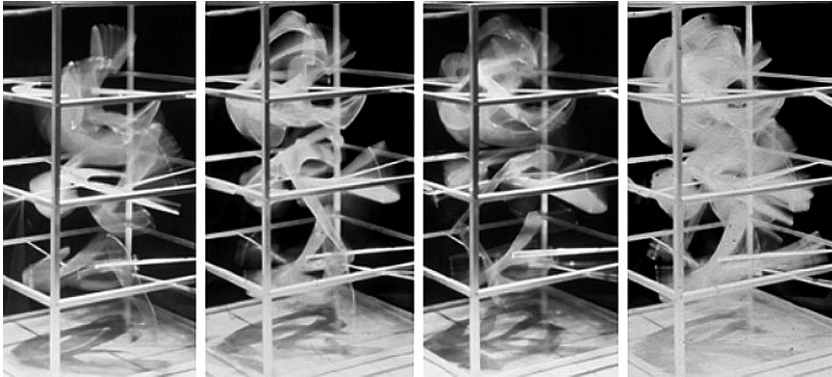 speeds (See Figure 71). The simulation of these techniques in the digital model was not as successful, though we can assume that a more in-depth investigation would produce new results.
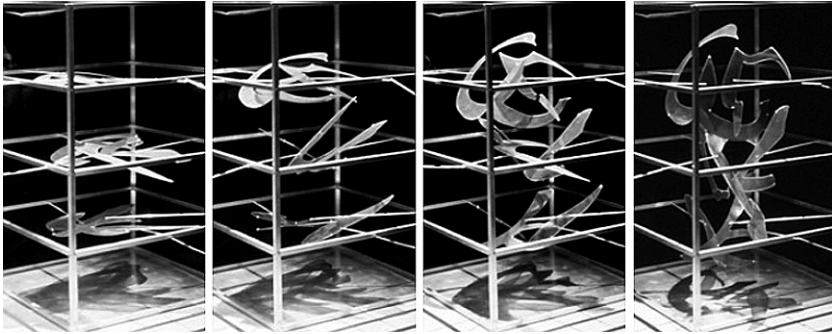
Figure 71 Registration of positions (time sections) of movement.

Figure 72 Registration of movement with slow shutter speeds. This technique is well-suited to the use of the physical diagram as a spatial form generator.

The oscillation between digital and physical diagram fertilises the process and pursues it along multiple paths and according to different conditions. Since the virtual aspects, structures and events of the diagram are seamlessly processed into design (form and program) through a series of design techniques and strategic concepts the merging of physical and digital models help to make this translation from the digital represented diagram to the

physical represented diagram and on to the concrete model that investigates tectonic and programmatic issues.[102]

The most difficult task is to maintain the performance and the events that the dynamic generative diagram produces. These are easily lost in the translation process. Further explorations are needed to exploit these aspects in a better way.

3.10.6. From generative diagram to program

Traditionally the building program has been the way in which user information, spatial requirements and functional relations have entered the design process. Since the needs and specifications change very fast, program is by many designers regarded as something dynamic. Program is regarded as the framework for a field of dynamic events rather than the precise formulation of strictly defined functions that are regarded as fairly stable. This perspective of the dynamic program demands that we deal with flexibility and change in a more intense way than before. Programmatic issues need to be treated on a level of adaptability and change. How do we plan for unforeseen futures? [103]

One strategy is to loosen our controlling grip on the process. The idea is that the least flexible solutions are those that are designed perfectly for well-defined programs. Less perfect, unfinished and more flexible solutions would in the long-term perform better. How do we design for the open-ended and 'imperfect'?

The use of generative material as an 'untamed' path in the design process can be regarded as one of many possible answers to this question. Generative material can be used for suggestive purposes, to test adaptability to unexpected events or to rehearse uncontrolled scenarios. [104]

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[102] Both representations in fact being analogue we intend to create a topological transformation between the media.

[103] During this work I was made more aware of the debates on planning versus non-planning that have been saturating architecture and urban planning for a long time. The question of how to plan for unforeseen futures is answered by some through a grid as an extensive organisation that can order a multitude of distinctive typologies, (Koolhaas); some others may argue through a 'blank' space that has no direct reference to existing typologies, (Kipnis,). (Hensel, 2005)

[104] Here we remind about the earlier discussions and references like Bettum and Hensel on dynamic planning strategies and Lynn on the wildness of the computer (Bettum and Hensel, 2000) (Lynn, 1999).

From coding to dynamic program

The use of diagrams to inform and develop programs implies that one especially looks for interplay and relations between different force categories. The structural qualities and the dynamic evolvement of the diagram have the potential to serve as templates for the development of dynamic programs. The diagrams could be used in at least two principal ways:

1.) To identify the relational categories and to derive principles from the diagram. The principles are generic and can be used in other situations. (Samples shown above).

2.) Use of generative diagrams as templates to inform program. The diagram influences the qualitative details of distribution and relations in the program.
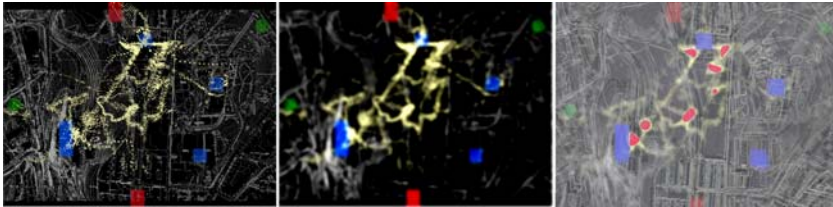
Figure 73 A particle animation used as a graphical template for the distribution of attractors on a site. (Ambient Amplifiers 2000)

The image above from the project Ambient Amplifiers[105] shows a still from a particle animation used as generative diagram to inform the distribution of an art, science and leisure program in Tøyen Park in Oslo. The concentrated areas were reached through graphic processing of the diagram. They indicate the distribution and location of art attractors. At this stage they were not yet defined, but they were later developed into locations for art pieces, event spaces for cultural activities and art pavilions. The relations to the existing art, science and leisure institutions was negotiated towards the location suggested by the diagram.

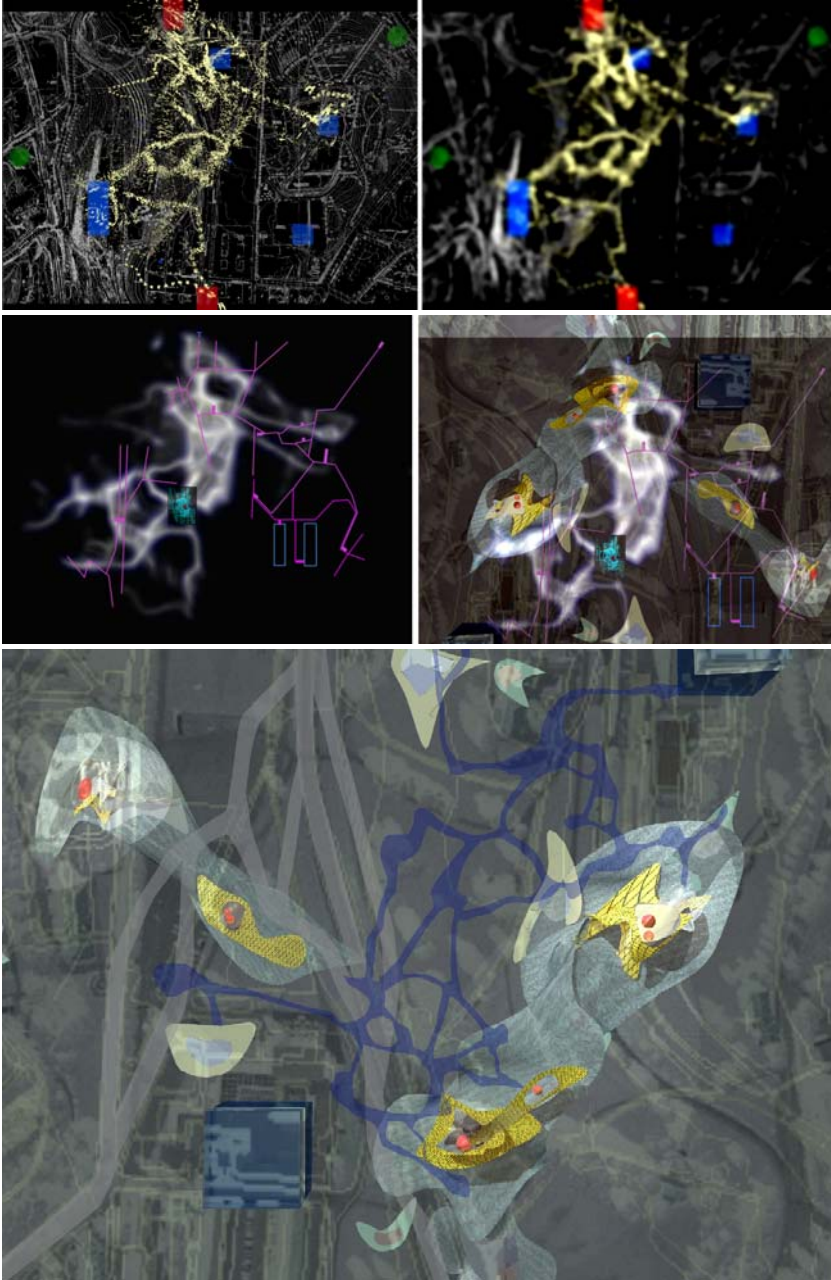[105] The project will be presented more in detail in part 5.

*Figure 74 Several stages of the development of a site plan based on the
implementation of a colour graft as a template. (Ambient Amplifiers 2000)*

The image series above shows the development of a system of hard surfaces in the Tøyen Park. The system was not designed as traditional footpaths following main directions of imagined use, but is laid out more as opportunities for incidental exploration walks and playground surfaces. They negotiate the current sharp division between hard surfaces (streets, foot walks) and soft surfaces, (grass). This negotiation is achieved through both the organic layout of the plan, which initiates alternative uses of the surfaces and through the differentiated use and variation in the surface materials of the hard surfaces. These will vary in roughness and sometimes blend with the grass. The generative diagram initiated a revising of the programs of the surfaces in the park.

Through adaptation and negotiation, the different site-specific, programmatic and diagrammatic entities could be related and fitted to each other. As input to inform and articulate the program, the generative diagram is used as a "resistant agent" in negotiating how the program is distributed. A negotiated set of generic information will give a more articulated, suggestive and adaptive form of programmatic organisation.

3.10.7. Dynamic generative diagrams

Recent work by OCEAN NORTH contributes to our experience of how the generative diagram can be used when we work with time. The generative diagram unfolds over time through animation processes. This we call the dynamic generative diagram.

Dynamic diagrams have been a theme in architecture during the last few years, introduced by Greg Lynn. (Lynn, 1998a) Later sources are William Braham (Braham, 2000) and Ali Rahim (Rahim, 2000)

The unfolding of time-based sequences of events is inherent in any program and hence in architecture. Such sequences operate in fields of parallelism (time), mutual influences and relations called Channelling Systems[106]. The diagrammatic force-space is central to the understanding of any program which involves artefacts. Programmatic issues need therefore to be treated in the context of duration, adaptability and change. The generative material can be applied to the diagrammatic field of forces to articulate it qualitatively, in a similar way to how landscape articulates travelling. But since form also is able to trigger program (to host, embed, "dock" and spin-off events) the qualitative articulated treatment of form generates a seamless interrelation between form and program. We realise that much of the environments we plan for do, to a large degree, not perform as planned. Instead there is a significant degree of opportunism that triggers actions. We wish to design for

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[106] Chanelling Systems see AD spring 2000 (OCEAN)

both open-ended spaces and user involvement. A non-referential heterogeneous space offers more opportunity. Non-referentiality keeps the so-called 'user' in an investigative state, as there are no established references of use, while the highly articulated environment offers many different opportunities to, for instance, occupy surfaces of different inclination. In our work with dynamic generative diagrams, we have investigated the potentials of designing generic but still articulated geometries to provide for environments for opportunistic use. Rich and generic geometries will allow for a certain palette of events to take place while excluding some others. There is a mutual influence between the user and environment:

*Form follows function < > function follows form*

Louis Sullivan 1896:
Form ever follows function

Winston Churchill 1924:
We shape our buildings and afterwards our buildings shape us

Steward Brand 1994:
Function reforms form, perpetually.
(Brand, 1994)

The generative diagram allows for a flexible approach to the relation between form and function. First of all, we recognise that both functionality and form are not fixed parameters but they constantly develop and influence each other. Secondly, we recognise that form is not only an expression of functionality, but that function or action is actually guided and influenced by form. In many cases we operate as opportunists in our environment. A stone maybe used as a resting place inducing a potential chain of events like resting, feeding, meeting, reading and others. A certain un-programmed geometrical shape has the potential to trigger events and to host them. We dock into geometries and land our spontaneous activities on suitable shapes.

Generative dynamic diagrams can contribute to the creation of generic potentials in our geometrical environment. A fold in a plane might provide for more varied use.

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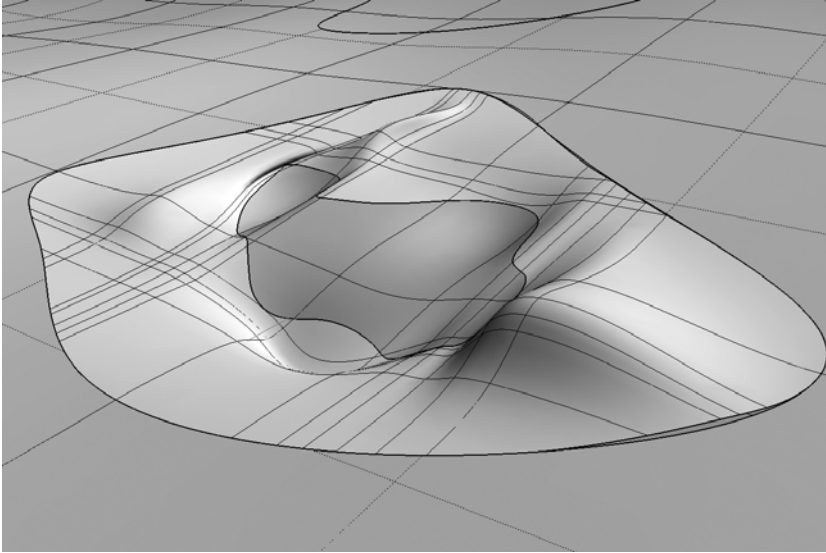
Figure 75 We speculate that the generic articulation of the field in a park will provide the triggering and docking conditions for events more than the flat plain. The palette of imaginable events span from using the geometries as furniture to territorial barriers and spontaneous play. (Ambient Amplifiers)

The generative material introduces qualitative features to the program. It gives form to the forces and therefore has implications for the very core of design, giving form and hence design creativity.

The generative material can be used for suggestive purposes, to modulate gestures of actualities, to rehearse triggering conditions, adaptability to unexpected events or uncontrolled scenarios.

Generative scenarios

All our designs, whether on an urban scale, building scale or product scale are likely to be used in unexpected ways or contexts and will have unpredictable futures. In this respect, time becomes an ever more necessary element in the comprehension of the urban fabric. We wish to know the future, since urban dynamics generate uncertainty through the continuous production of future possibilities. Through scenario techniques we can tell well-grounded stories about our possible futures, prepare both conceptually and practically, and embed adaptability in our designs. Though scenarios cannot be taken as true predictions, we can say that they are potentially true on a structural level.

Scenario techniques were invented in 1972 in connection with the oil crises which clearly demonstrated the failure of linear historical prognosis. At Royal Dutch/Shell, a group was established to study parameters that could possibly have significant influence on the oil price. Scenario methods have never been intended to predict the future but they were used to counter balance the view that prediction is impossible. Scenarios were meant to visualise the most important forces which were crucial to how a system potentially could develop in several different possible directions. (Thom, 1972) Scenario techniques are a tool intended to prepare and rehearse for several different future possibilities, and to test the adaptability of the system. Hypothetically if the system demonstrates the ability to adapt to several invented scenarios, it should be better suited to coping with unexpected events in real life. Following this logic, the scenarios should rather be extreme (worst case / best case) than realistic. An extreme scenario would test the system more thoroughly than a more realistic scenario. Hence if the system can cope with extreme situations it is also likely to successfully tackle milder variations of the same problems. Adaptability has to be built into the system on a structural level rather than on an explicit level.

Steward Brand suggests scenario planning as a tool for buffering buildings against future unforeseen changes. He states: All buildings are predictions. All predictions are wrong and:

> The iron rule of planning is: whatever a client or architect says will happen with a building, won't. Architects always want to control the future. So do clients. (Brand, 1994)

Scenarios introduce the dimension of time into the design process. Generative diagrams with a time dimension (animation or other time-based processes) can be seen in relation to scenarios as indicators and structural generators of possible futures.

Especially Greg Lynn has contributed with crucial new ideas and techniques, on animation.[107]

Dynamic generative diagrams help us to investigate how different structural organisations might evolve and interact over time, and establish qualitative principles for such events. They help us to negotiate time-based changes between interacting systems.
They help us to build in adaptability on a structural level. They also help us to develop concepts around timing of events and sequences.[108]

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[107] Here also to be mentioned Ben van Berkel, Stan Allen, Manuel De Landa, Peter Eisenman and Sanford Quinter. A collection of essays with the mentioned authors and additional ones is to be found in ANY magazine 23 1998.

The idea of using dynamic generative diagrams to inform program comes from the observation of the fluid nature of real-life programs. Programs change over time, they influence each other with varying intensity and they are frequently turned on or off they pulsate. The program of a museum is turned off when the museum closes down, or it transfers to a marginal subprogram performed by the night guards watching over the museum treasures.

The dynamic generative diagram will interweave the principles from the diagram into the program. The hypothesis is that these principles will, when embedded in the structure of the program, render the program in a way that makes it able to adapt to various conditions. The need for adaptability comes from the need for architecture to involve with context. A holistic view of context means to influence and be influenced by topological, cultural, sociological and political surroundings. Since these relations tend to be of tremendous complexity we seek to integrate the principles of adaptation and influence rather than to solve these situations as singularities.

3.11. THE QUESTION OF SELECTION

The resulting material from an emergent process (e.g. an animation) is so huge that introducing some data reduction strategies is usually unavoidable. The first instance of data reduction occurs in the very technique of reproducing motion on a media: the frame. Instead of an evenly floating change, which would produce an infinite amount of data, the illusion of motion is produced by the fast display of a large number of slightly changing images. Each of these images is a stop frame. Whatever design intention we have in the further use of the material we normally need to reduce the data further, selecting a limited number of these stop frames as a starting point for our design.

This forced step in the process seems to contradict the inclusive process. My approach is to view the material of the process as pulsating. It expands and

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[108] See also Strauss and Corbin (p. 143) on process. Change brings time and movement into consideration. Strauss and Corbin isolate change as a phenomenon, indicating that change is not always taking place. They also indicate that not all change "points to process" (p.151) But later they indicate that time is always at play in the phenomena grounded theory is tailored to investigate: " The manner in which any phenomenon is expressed is through purposeful and related action/interaction sequences" (p: 159). See also page 150. The shape and form of change and a listing of properties of change. (Strauss and Corbin, 1990)

retracts repeatedly and through this pulsation of the process-data, the process is driven forward. The stages of reduction bring with them the necessary essence or traces of the richness from the preceding expanded stage. In many cases it is mostly a question of perception. We need to fragment and split up the richness of the inclusive process to be able to perceive its details and layers.

The other aspect is that ultimately an inclusive process like a process based on versioning will demand a decision of selection from amongst the many instances. One could say that this singular version includes the others since it is a snap-shot of a soft movement from one extreme to the other.

The question of how one selects samples from the generative material is difficult to answer in a simple way. However this is not an alien problem but a central task in any design process, including the traditional ones. The belief that form follows function, leading to the logical continuation that for each problem or task there exists an ideal form, and that the designer's task is to search for this form and get as close to it as possible, has definitely been questioned and discarded long ago. It has been replaced with the understanding of the complexity of functionality when objects operate in real-life contexts that immediately entangle the artefact in a field of negotiations. All design solutions should place themselves along these gradients of negotiations between the parameters at stake, and when we know that for each situation there are numerous parameters influencing the arenas where the artefacts are meant to operate, the possible solutions in any case render a logically based investigation impossible. Another way of saying this is that there is no such thing as one correct solution or ideal solution, but there are high numbers of possible solutions depending on where one places oneself in this field of negotiations. The different solutions will perform differently, but within reasonable frames it is not possible to state that one is principally wrong.

But this insight into the complexity and relativism of negotiational fields in which artefacts operate does not necessarily lead to relativism as a consequence, where any solution is equally good depending on the perspective of the evaluation. Still we will be able to argue for certain more-or-less substantial or absolute qualities. One of these quality parameters is how well the artefact actually embeds and engages in the fields of negotiation. Despite the situation being complex and hard to understand, it is still possible to judge the artefacts according to performance (function) but there will be fewer simple answers and more weighting of consistency and relevance towards the complex context. Our evaluation of the artefacts will also resemble negotiation, just as has already occurred in their production.

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Another means of selection is according to subjective preferences. We simply pick what we like. Individual preferences vary and are influenced by background, education, cultural context, etc. Though they are fluid, personal and sometimes impossible to argue for, they nevertheless play an important role in any design process.

Structural features also fall into a similar category. We can select samples based on the intuition that they have the potential to be developed according to our design intentions. This means that we rather look at the samples as potential starting points, templates, catalysts or structural diagrams than as formal inspiration.

In most selection processes, either when selecting a few samples from a huge output from a generative process or when making decisions in a traditional normal design process, all or many of the mentioned aspects are under consideration. To rationalise these moments of selection is not possible, simply because all elements together produce too complex a picture and the possible solutions are infinite. But designers have long ago developed strategies to make decisions. Several of these strategies are simply there to reduce the field of possibilities and to establish frames that are small enough to work with. Many designers develop styles and repeat certain themes. But still the possibilities are vast within those fenced areas. To support a framing of the project the designers often work with laborious analyses of possibilities, relations and constraints. The potential of normal design negotiations helps to understand the operation of the artefact and to make decisions as to how the artefact should embed into that field and engage with surrounding parameters. But this brings the design only partly to its conclusion. No matter how laboriously this investigation is conducted, still this does not lead to a complete design. At its best this can inform certain aspects of the design. Certain aspects just need to be designed without being informed by operational parameters, and when the amount of parameters gets large there may be no way of synthesising them in a logical way. To overcome this last difficulty, the designer relies on intuition, experience and craftsmanship, rather than on cognitive based decision-making. This profession-specific intuition is not at all mysterious but simply based on long-term education and professional experience. Such intuition involves synthesising a complex field of parameters through tentative suggestions and testing a limited number of individual solutions (chosen from millions). It also synthesises these parameters with material solutions based on experience, formal, visual and aesthetic individual preferences.

These selection processes are craft-based skills rather than cognitive exercises. Common to all skill-based knowledge (tacit knowledge) is that one learns through rehearsal and practice rather than study. The selection is done on the basis of a subjective forecast of the potential of the material to be

developed into a design. At an early stage, we train the ability to recognise the features that could potentially contribute to a challenging and exiting result. Sometimes this insight comes from seeing the complexity and layering of structures in the material. Depth, complexity, colour information, structure, unusual and outstanding elements are all part of this.

3.12. SUMMARY AND CONCLUSION OF PART 3

When digital technology enters the design process and the creative work of the designer, it brings with it a whole range of concepts and ideas, especially during early stages of the process. The result is that the design process is altered and expanded and virtually forced into a more inclusive stage resulting in more complex and elaborate processes. Some of these elements are well known, for example emergence in design or generative design. Others are less recognised and I have attempted to raise some of these issues in this chapter. Such issues include the importance of generative design techniques as creative devices to break schemata and to bring the process slightly out of the cognitive control of the designer. Another issue is the emphasis on visual thinking – a spin-off from the fact that design computing is largely a visual activity, powered by the powerful and cheap display adapters. In addition, I have argued for a more conscious relation to the way we transform information with the help of the computer. This, in turn, led to the distinction between recoding, translation and interpretation.

The generative diagram is the central device that gives the techniques and concepts a framework of operation.

4. Ways of Working: From Design Practice towards Theory and Digital Design Methods

In this part of the thesis, I attempt to conceptualise and categorize various techniques in order to look at them in more detail. This gives a fragmented view of the different techniques but an overview of the rich possibilities that are provided by the use of computers in creative design.

Fragmentation and categorization are useful for looking at the different techniques specifically and for developing our knowledge of concrete issues of digital generative design. But it also has a limitation. In reality a single technique is seldom used alone but rather in combination with other techniques. In part 5 this relation and the more complex whole will be explored.

4.1. INTRODUCTION

The purpose of this study is to create an overview of my practice, to pinpoint certain phenomena in that practice, to generalise principles and to suggest categories of techniques. The process of categorizing, sorting and mapping a practice where a complete overview has not previously existed creates a meta-level of knowledge.

The aim of this study is to conceptualise and categorize the techniques, ideas and intentions that have become central in my practice. My intention has not been to try to create an authoritative typology with standardised terminology for more widespread use, but rather to establish an overview in order to be able to discuss similarities and differences between the found categories and to see whether these can be formulated in new concepts. Creating categories is part of the investigation method that was applied in this study. This method is a loose derivation from Grounded Theory. The categories are fluid and they changed and developed during this study and will hopefully develop further in the future and maybe inspire other people.

4.1.1. Practice-based research

This study is based on my own practice. It is therefore a first-person practitioner research.

My work spans from furniture design, interior architecture to industrial design and experimental design. This thesis does not include the more professionally oriented parts of my work. This exploration is driven by my experimental work. The theories and textual manifestations are the devices for sorting and systematising and conceptualising practice. This study is explorative, heuristic and is a documentation of the current state of the investigation.

4.1.2. Visual material is central.

This thesis is dependent on the visual material which consists of samples from my experimental practice and teaching. The images play an important role in understanding the thesis. The image texts are also essential and are more important than is often the case. They explain and point to the visual material and are in this thesis regarded as methodological tools for an ostensive method. This means that this thesis cannot be understood without referring to the visual samples.

4.1.3. Two investigation paths

The material has been investigated along two paths:

- The first path (part 4) systematises the techniques. The analysis is based on open coding where distinct phenomena are separated and then sorted in categories according to similarities and differences.
- The second path (part 5) sorts the techniques according to intentions. Looking at this field from the perspective of the designer's intentions relates the techniques to a wider context. Since an intention-driven project normally involves the use of several techniques, it also relates the techniques to each other.

While part 4 presents a specific and fragmented picture, part 5 provides a more holistic overview with emphasis on the connections and relations between the different parts of a complex design process.

4.1.4. Achievements

This study aims to explore my personal practical work and material from teaching that is related to that work. This implies that the findings and inventions achieved do not claim to have general value. If other designers were to use these techniques it would not necessarily result in the same

output nor would it result in the same way of thinking. Through this study I am offering insight into how I have done things. The general value of this insight may be summarised in this way:

The study opens up a field for investigation and discussion that has so far been very visible but not discussed in depth from a method perspective. In general, the study can be a valuable model for people who want to get a better overview and to raise awareness of their own and others' ways of working. The thesis provides an expansion of the way we can relate to practice in research. It suggests a way of relating practice and theory, and reflection and analysis which is generic and could be implemented and developed further in other practice-based investigations. I think the thesis demonstrates that design actually is a form of investigation but it also shows that this form of investigation only becomes valuable when it is externalised. Therefore the textual part of the thesis is as important as the practice, without devaluating the practice as the main engine of investigation. The thesis also demonstrates methods which are appropriate for this kind of investigation. Theory and practice supplement one another.

The study provides a substantial contribution to the investigation of how digital technology influences the design process. The study provides only a fragment and does not intend to give generic or complete answers. These answers may eventually come from other similar studies in this field.

Hopefully this study also can achieve additional goals:

- Inspire other designers to adopt and develop new ways of using the computer in the design process.
- Propagate a way of thinking and researching one's own practice that would have the potential to develop that practice.
- Enable designers to react faster to technological changes.
- Suggest research techniques that can help to investigate the potential of new technology, and how this influences the design process.

4.2. METHODS

So-called "first-person practitioner research" is not well established as an accepted mode of knowledge production. Therefore I have found it necessary to include a brief overview of the most central aspects of this approach and how they relate to other similar and more established research areas.

The conditions for practice-based research to be successful are embedded in the individual experience of the practitioner, hence the term "first-person practitioner research". It builds on first-hand knowledge, practical research

synergies and a focus on relevance as described by Colin Robson (Robson, 1993). In creative emergent design practice which is now becoming necessary for designing with digital tools, practitioner researchers find themselves in situations in which clear models and methodologies do not yet exist – these are being developed through practice. The challenge is to be able to reflect on this practice and to try to move from critical description to analysis.

Practice-based research is not a linear process but a process where analysis, data production and data collection take place in parallel and mutually influence each other. (Fettermann, 1989) pg. 13

The research perspective in this thesis also leans on activity research described by Nardi.

> Activity theory is a powerful and clarifying descriptive tool rather than a strongly predictive theory. The object of activity theory is to understand the link between consciousness and activity.   Activity theorists argue that consciousness is not a set of discrete embodied cognitive acts (decision making, classification, remembering), and certainly not the brain; rather, consciousness is located in everyday practice: you are what you do. (Nardi, 1997)

I regard activity theory (as grounded theory) as related to my approach, but whereas activity theory is largely descriptive, what I am doing is largely generative. However, the field of investigation is similar: an activity.

4.2.1. Explorative and generative research

This study is an explorative, inductive and generative investigation into the field of practical application of computer-aided creative design techniques. This means that there is no clear initial hypothesis or research question being tested. New concepts and techniques are developed through the investigation. This is an inductive bottom-up approach. A feed-back cycle and heuristic spiral is established, where practice and theory modify each other through the process. In this way, the research feeds back into itself through accumulated experience gained from practical exercises. However, to be of any use, the feedback must be analysed and categorized, and the techniques developed and discovered through the research must be systematised.

This practice-based method could be called evolutionary since every step taken feeds into the next step. There was no plan or foreseen goal nor was there an initial hypothesis to be tested. Since I found very little systematised knowledge or examples from practice-based research in the field of three-dimensional generative and emergent design it needed to be explored in the

manner of moving into the white spots on a map. One can make certain assumptions, but no hypothesis. The closest analogy to this process is found in action research as described by Kurt Lewin as:

> ......a spiral of cycles of planning, acting, observing and reflecting (Robson, 1993).

This leads to the notion of theory as process. Comparative analysis is described as a strategic method to generate theory. The generation of theory in this context is seen as an open-ended process, or as Glaser and Strauss put it:

> .....theory as an ever-developing entity, not as a perfect product (Glaser and Strauss, 1967).

The practitioner researcher can use open-ended techniques to establish a distance between the practitioner as conductor and the practitioner as researcher. Amongst such techniques are "big net approach" and unfocused investigations (Fettermann, 1989) (Jorgensen, 1989). The reality of conducting complex real-life studies also renders exclusively rigid methodologies obsolete. The real-life researcher needs to be able to adjust to the issues that the qualitative research generates (Fettermann, 1989).

4.2.2. A first-person approach

The insider practice-based research conducted in this study I term a *first-person approach*.

A first-person approach draws on the direct detailed knowledge of how the material was produced but it is also concerned with refining this knowledge during the research. A larger survey might have contributed to the validation and generalisation of the study but it would without doubt have competed with the resources needed for the practice-based part of the study. This could of course have been solved through team-based research but this is hard to combine with the first-person approach. Such a team would have to consist of practitioners on an equal level who would be able to exchange ideas around the topic. It was not possible to establish this at the time of the start up of this study, mainly because the resources for this approach were not available and the general interest for the topic was not yet widely developed. Regardless, the problems of organising a study involving more people and resources and with emphasis on maintaining a dialogue and collecting considerably more data, and the subsequent problems of coordinating and systematising the study would conflict with the personal nature of the first-person approach. Later, the study gained from discussions with some of my colleagues (e.g. Natasha Barrett and Michael Hensel). An interesting

potential development of first-person practitioner research would be to take part in networks with shared themes in which individual projects could feed on each other.

4.2.3. Analysis

The method for analysis is loosely related to Grounded Theory. In this approach, empirical material is investigated in order to find discrete phenomena. The phenomena are sorted into categories which are found from comparing the phenomena. The analyses are conducted as open coding and comparative discussions (Glaser and Strauss, 1967). The method is applied in a "soft" manner with discussion as the central element. (Førland, 1996) This also relates to what Mats Alvesson and Kaj Sköldberg call Reflexive Methodology (Alvesson and Sköldberg, 2000).

The core of Grounded Theory is open coding. Open coding is based on the finding and labelling of phenomena in a field. The phenomena are categorized and analysed and from this process a generalised theory grows. It is an inductive process, in contrast to the deductive process where a theory is tested through experiments. Grounded Theory prescribes a detailed methodology which is meant to contribute to its validity.

A fully-fledged study in the way prescribed by Grounded Theory tends to obstruct a first-person approach. In a first-person approach, observation and creation live in symbiosis and synergy. The strictness which is necessary in an approach based on observation would not allow for the flexibility needed in a process of creation. The need for rigour would easily "freeze" the practice into static categories and would reduce the tentative and intuitive elements in the process. The process of creation continuously overthrows and remodels what is observed. The interpretation and adaptation of existing theory, such as Grounded Theory, to make it suited to specific cases is recommended by Anselm Strauss. I also gained confidence in such an approach through reading Kari Thoresen's thesis on computer use. (Thoresen, 1999)

A first-person approach needs methods that feed into both the practice and the reflection and which provide the process with energy and drive. A heavy resource consuming method will disrupt the flow of this type of investigation. Csikszentmihalyi demonstrates that a creative flow is always important in any kind of research (Csikszentmihalyi, 1996). But this becomes especially important in a first-person approach where practice and theorising are so closely interlinked.

4.2.4. The Material

The material discussed in this thesis is almost entirely based on my own production, individual projects or cooperation with colleagues. In addition, the results from teaching workshops and projects have contributed substantially to the material. Teaching has been used to investigate ideas and concepts further than what would have been possible with my limited resources or those of my colleagues. I have only included material about which I have first-hand knowledge, that is the precise way the material was created and used in the design process. This choice was made because it takes direct advantage of my position as practitioner researcher. (First-person approach or insider perspective advantages (Robson, 1993)). Investigating other practitioner's material was considered not very useful despite the obvious advantage of broadening the material, introducing comparative studies and maybe reaching more generic conclusions. The reason for my restrictive decision is that such an investigation would not be possible to combine with a first-person approach. The need for keeping focus on the practice and investigating it in depth would not be possible to combine with a broader survey-based study because of the considerable demand on resources that would involve.

The work presented here comes mostly from projects done together with colleagues in OCEAN NORTH and from teaching students at the Oslo School of Architecture. Some of the work was also carried out in collaboration with the Architectural Association School of Architecture in London and in workshops held at other schools.

The material is the result of design in practice. The resulting analysis should not be seen as a product of knowledge already embodied in practice; rather it surfaced through the practice and as a result of the practice. The analysis is the result of a personal need to give voice to a reflective and analytical dimension of my work because of the difficulties of finding a theoretical frame or a tight theoretical nexus. The role of reflective practitioner is the best way of attaining this knowledge.

4.3.1. Categorization

Categorization is here used as a process tool and the categories are not meant to be absolute but are flexible and dynamic and intended for constant development and modification by whoever gets inspired by this text. I start with a brief overview of attempts of categorization in the field of design computing. Then I present the categories of digital design techniques I have developed, outlining their differences and similarities which were partly developed and partly found during the study. The material and the derived categories have emerged from use and practice, whereas the intentions and concepts behind the practice are discussed in the next part.

Categorization is a way of creating a map of a field that may be known in some way in the form of experience, tacit knowledge or skill, but where an overview of the landscape is lacking. By finding and labelling the singularities in an unknown landscape, the basis for a complete picture of the nature of the landscape emerges.

The type of categorization at stake here is not a deductive one as found in statistics, where e.g. a population is sorted into pre-agreed categories of age, gender or income. My approach is a softer approach where the process of fragmentation, comparison, differentiation and the creation of a vocabulary is more important than the consistency of the catalogue. The categories are "found" in the material by observing phenomena and comparing them in search of similarities or differences.

This type of categorization is simply the best way to uncover patterns of similarities and differences. It makes explicit a vocabulary of ideas and concepts that might have been present for a while but may be hidden in an intuitive and tacit way of working. Categorization is a fragmentation strategy which implies that it has its limitations. But the fragmentation allows singular concepts to stand out clearly. The most valuable element in this approach is the process and the discussion that comes from the difficulties in the categorization. Through these discussions, a greater depth of knowledge is developed. The arrival at clear, consistent and solid categories or the general adaptation and use of the terms is of less importance. Therefore this type of categorization is a process-tool with no final product but where we can summarise stages of development and point to possible further investigations.

The fragmentation of the categorisation- process uncovers also connections and similarities and relations between different approaches. The singular

fragments stand out clearly but when we look at the application of these fragments the picture becomes very complex. To overcome the weaknesses of fragmentation (analyses) we need to mirror this approach with an approach that pulls the strings together and that looks at more complex wholes (synthesis). In part 5 the techniques will be discussed according to intentions which allow a more complete picture. In the end this leads to a more conscious approach to hybridization in design processes.

4.3.2. Mapping the field of design computing.

There exists no authoritative categorization of design techniques, methods and approaches in digital design. Most of the existing categorizations, with few exceptions, are fairly general and are useful for a broad overview but do not address the detailed level of creative digital design practice. Most of them do not really contribute to the analysis of possible ways of working because they are quite superficial, fluid and over-branched and sometimes unclear. They seldom address the issues of how we work and what we do with the computer in any detail. This is largely because most such work does not set out to be extensive categorization studies but simply aim to shed light on certain central themes. I was unable to find any work in this field which included categorization as I have attempted in this thesis. The study that comes closest to my work is the categorization by Peter Eisenman in his book Diagram Diaries (Eisenman, 1999a) Unfortunately this is not explained in depth and the reader is left to interpret the intentions and underlying method of categorization.

Amongst CAD systems we can find a sort of semi-official categorization which most, or many, of the CAD software developers have agreed upon:

- Parametric construction: all geometries are driven by parameters like measurements or equations.
- Explicit modelling: the geometries are not driven by parameters but designed with the use of mouse input in a process that is more like drawing: click and drag.
- Variometric construction: combines parametrically driven geometries with the freedom of explicit modelling
- Freeform modelling: surface modelling where spline surfaces are constructed and modified.
- Visualization and animation systems.

These categories indicate several different ways and areas of working. Behind this we can see categorization according to the geometric libraries developed by the CAD mathematicians. Each modern CAD system integrates

several of these libraries. Also advanced analysing, co-operation and logistic systems are formulated in concepts that are sometimes used by several producers of CAD-systems.

Such categorization from the software developers is useful but only to a limited degree does it say anything about how we might work in a creative process. We have to look to other sources to find categorization attempts more relevant to of the study of digital creativity. One example of thematisation of the field is found in the book *Architecture in the Digital Age* edited by Branko Kolarevic (Kolarevic, 2003) Kolarevic does not actually categorize the field in his introduction, but he lists some of the conceptual techniques that are found in digital architecture: "Topological space, Isomorphic surfaces, Dynamic systems, Key-shape animation, Parametric design, Genetic algorithms". Later in the same book in his article *Digital Morphogenesis* he introduces the themes as titles of chapters which can be interpreted as a form of categorization. First he considers some conditions for the technology like NURBS, Topology, non-Euclidian space and Parametrics then he moves on to themes that are more conceptual: Dynamics and fields of forces, Datascapes, Metamorphosis, Genetics, Performative Architecture.

Kolarevic's categories or phenomena span over CAD technology (NURBS, animations) geometrical-mathematical issues (Topology, Isomorphic surfaces) and current thinking in architecture (Datascapes, Performative architecture). One could say that this listing of phenomena is mostly based on a description of possibilities. The phenomena say more about the means and theories we have in this field than about our intentions.

In the review of the entries for the FEIDAD award (Liu, 2000)Yu-Tung Liu divides the field of digital architecture into four categories (Liu, 2002):
- Liberation of form and space
- Evolving concept of space
- Parametric intelligence of design
- Coexistence of physical and virtual cities

Yu-Tung Liu's four main categories are more about intentions than about methods and means. They roughly match the themes I consider in Chapter 5 of this thesis.

In order to map and sort this complex field, I suggest that it is useful to use two main perspectives:

How: the finding, categorization and development of techniques and methods
Why: the description and discussion of intentions in creative computer use.

The most elaborate categorization I have found is the table at the back of Peter Eisenman's 'Diagram Diaries' (Eisenman, 1999a). The table lists 40 'tools' and maps them with a list of Eisenman´s projects. The list is sorted into two groups, formal tools and conceptual tools. The two categories roughly match the two main divisions I make in my investigation.

Many of the items listed by Eisenman are clearly technique-based concepts with a close link to CAD:

> Extrusion, twisting, displacement, morphing, intersection, projection, torquing, distortion, warping, scaling, rotation, doubling, inversion, tracing, blurring.

Others are connected to more complex concepts of design thinking and some are based on design strategies:

> Interweaving, disassembling, interference, superposition, nesting, repetition, imprinting, transformation, mapping, artificial excavation, folding, grafting, layering, montage, voiding, decomposition, striation, gridding, laminar flow.

A few of the items, like *shifting* or *slippage,* do not fit easily into any of the groups.

Eisenman maps the items according to his two main concepts, interiority and exteriority. It is quite obvious that Eisenman´s categorization indicates that a seemingly simple technique like scaling or rotation implies more than the explicit operation. I think he has taken into consideration much deeper implications than what follows from the simple geometric operation. Therefore it makes sense not to sort the different items into for example low level and high level operations (how and why). I am entering the field from the other end. I want to separate the intentions from the techniques to create a necessary distance to my material.

The analysis
The analysis presents the systematisation of the techniques found in the study. They are sorted into two main groups:

- Generic techniques that are derived from computer use but develop independent from media.
- Specific techniques which are dependent on the particular use of the computer.

The distinction of phenomena was based on external criteria, what the designer (in most cases myself) actually does to induce the diverse processes, and not on what internal motivates he or she might have. A phenomenon is delimitated by typical characteristics.

In my attempt at categorization, I think I manage to contribute to greater depth and clarity and awareness of details in the ways we potentially can use digital technology in a creative process. I achieve this via a fragmentation strategy. The complex whole is divided into distinguishable phenomena. This is a traditional approach in science which is frequently is criticised for loosing sight of the context and the relations between the fragments. This criticism also applies to my study. Categorization only helps to a certain degree. The found categories are clearly distinguishable phenomena, but when looking at real projects the picture becomes blurred because most of the principles that I have found normally appear together in a mixture. This is the main reason why some of the samples in this thesis appear in several different categories. Often several of the phenomena are found in each case. The picture is complex and the categories only help to look at fragments that are parts of a more complex whole. Categorization helps to introduce an analytical way of thinking about these techniques.

4.3.3. Generic techniques
Techniques which have derived from computer use but may be used in other media.

Certain techniques grew out of computer use (or from the period of development of design methods that were strongly influenced by computer use) have proved to be generic in that they are valuable regardless of which design media we use. The techniques can easily migrate from the computer to other media such as traditional drawing and physical models.

Generic techniques are principles found across the whole spectre of the work researched in this thesis. They are independent of the media, technology and the nature of the source material and they can be regarded as guiding principles which can take on different forms according to the requirements in each case. For example, the *reduction and expansion* of data is a principle that could be implemented in a long range of techniques both within analogue or digital media or it comes into play in the crossing over between media e.g. in the digitalization of a physical model where only a reduced number of measuring points are used or where rule-based geometries are used.

An interesting aspect of these techniques is that they can easily migrate from the digital realm and that when this happens it often results in a fertilization of the design process.

Such generic concepts found in this investigation are:

Translation
The manual translation of information from one representation to another. Involves interpretation. (This is treated earlier in part 3 as an aspect of the nature of computing.)
Example: The figures in an image that is filtered with Photoshop will in the end no longer be recognizable and will lose their representational meaning. The meaning of an abstract diagram will change if we are told what it represents. An abstract colour field can be grafted onto a site and start to represent forces and actors in that site.

Grafting
The 'injection' and implantation of data onto another data set.
Example: the merging of a colour graft with a site as in the Synthetic Landscape project. The technique involves negotiation and coding of the elements. Mentioned earlier in part 3.

Templating
The use of a generative sketch as an underlay for a designed form.
Example: The use of data-animated shapes in the design of the time capsule (a_drift) Templating is discussed earlier in part 3.

Scaffolding
The generation of a (dynamic) mediation device between the elements of a source material or generative diagram and a template.
Example: The skeleton animation for Tøyen Gate in Ambient Amplifiers. Scaffolding is discussed earlier in part 3.

Pattern recognition
Pattern recognition is not to be confused with digital pattern recognition technology. It is used here as human visual thinking, deriving certain structural features from visual and geometric material. Digital techniques are applied to reinforce visual thinking.

Real-life monitoring
The design techniques that start with real-life monitoring collect real-life information to inform the design process and apply digital techniques to reinforce this process.

4.3.4. Specific techniques

Techniques which are restricted to use on the computer.

By this we mean techniques that have emerged from computer use and that
are specific to computer use. They are not easily transferred into other design
media. Amongst the investigated techniques we find, animation and
dynamics-based techniques, data coding and recoding, parametric design
methods, genetic algorithms and mouse-based modelling and sculpting
techniques. The results show that in most of the cases that were investigated,
more than one technique is found within the same design process. These
principles can appear in separate phases of the process or in parallel or cyclic
processes. The following categories were created:

Direct modelling (explicit modelling)
The control vertices are manipulated with an input device (Mouse) and there
is a correspondence between the movement of the input device and the
deformation of the geometries. This is an established category in CAD
systems. It relates to direct form generation in the generic techniques but is
here exclusively linked to computer use.

Sculpting
In sculpting the geometries are formed with special software that mimics the
way we work with clay or similar materials. Either mouse with specialised
surface cursors (Maya) or specialised force feedback input (Freeform
Phantom) devices are used.

Recoding
Example: sound can be represented in a visual representation. An image can
be translated to ASCII code.

Data reduction and expansion
Data reduction and expansion is a technique where data generated in one
software package is recoded and read by another software package.
Discussed earlier in part 2.

Parametric design
The geometries are driven by input parameters. The change of the geometries
is driven by the parameters. [109]

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[109] Parametric Design is apparently used by different professions in seemingly
different ways. Architects use it as a general term for a design process that is fed by
information from real life or from internal forces within the design process. Originally
the term stems from the design of CAD software. When searching the net we hardly
can find any references from other fields. The following definition nicely includes the
main elements of parametric design in CAD systems:

Interactive Simulations
Virtual environments where the real-time interaction of the user alters and influences the environment.

System simulation
Resembling a real-life situation in a computational set up and letting the computer run to generate results that somehow mimic the real world.

Data recoding
To alter the meaning of information. Since all digital information basically is represented in the same form in binary numbers, it is easy to alter what the information represents.

Animation-based techniques
Animation-based techniques are most often crossover categories that can contain elements from parametric design, simulations or mouse-based modelling. But animation is so central in these new techniques that it appears as a category. When the animation process is central to a technique, it is classified in this category.

4.3.5. Table of techniques

Many of the categories are not so clearly limited and their borders are blurred. The most important aspects are the techniques. This is the reason why the following table is organised from the perspective of the techniques starting with the source material. Three techniques are shown on each page.

Parametric design is an important modeling paradigm in computer aided design. Relationships (constraints) between the degrees of freedom (DOFs) of the model, instead of the DOFs themselves, are specified, resulting in efficient design modifications and variations. (Yacov Hel-Or)
Parametric design systems are ready for ever more intelligent input and configuration of the driving parameters. One resent example is the work of Kristina Shea who developed a method called Structural Shape Annealing and a research software, *eifForm* (Shea, 2004, Shea, 2002). With these tools it is possible to generate large variations of e.g. dome structures that are structurally sound and buildable with no need of post-rationalization strategies. Mark Burry discusses parametric design in the rebuilding of the Sagrada Familia (Burry, 1999) (Burry, 2003) (Burry, 2004) Burry's work places itself somewhere between the hard nosed CAD parametric and the softer interpretations from the resent architectural discourse. He derives an analysis from Gaudies plaster models that implements parametrical modeling to geometries and so resembles Gaudies geometries. This approach is very convincing and it demonstrates not only the potential of advanced geometrical construction and analyses but also Gaudi's in depth understanding of geometrical-mathematical issues. For the designer the most interesting approach is to balance between these strategies.

Category	Translation.	Grafting.	Templating.
Technique	The interpretation and reconstruction of a design form one medium to the other.	Merging and negotiating and graphically blending an abstract and generic source material onto a specific and known material.	The use of data as underlay for a design.
Source material	Model of design or abstract diagram.	Can be a 2D colour map with certain qualities like blending borders visual depth and colour depth.	Any chosen material.
Processing	Manual reconstruction in another medium. Human rationalisation and interpretation is central	Graphic blending. Filtering and visual analysis.	The underlay serves as a design sketch. There is a close relation between the template and the design. The new design may serve as next template.
Tools	All kinds of digital and physical modelling tools.	Manual drawing tools, Photoshop	All kinds of digital and physical design tools, transparent drawing foils, redesign of versions.
Resulting process	A redesign of the design where human interpretation and rationalisation are important.	A continuous field that is articulated structurally but which resists typology as a basis for further design development.	The iterative development of a design through ever more precise and defined versions.
Projects	Chamberwork's translation of digital particle data into physical model and the manual digitalisation of the physical model.	Synthetic Landscape	Appears in all design projects.

Category	Scaffolding.	Pattern recognition. 2D patterns.	Pattern recognition. Time and space patterns.
Technique	The use of a model to create a design space for a design	Contrasting blurring, edge sharpening and others. Diagramming, coding	Contrasting, blurring, edge sharpening, Diagramming, Rhythm analysis, repetitions, intensity, monitoring.
Source material	Any chosen or generated material. Many diverse processes are imaginable.	Graphical filtering of still images and 3D spaces.	Graphical filtering video.
Processing	A loose relation between the scaffold and the design. The scaffold organises the space more than the design and serves as structuring device and place holder.	Manipulating the filters.	Manipulating the filters. Intuitively or systematically according to set rules.
Tools	Could be any physical or digital tool. Digital tools are preferable in some cases because they allow for a dynamic relation between scaffold and design.	Photoshop	Video editing systems, After Effects, Photoshop, Flash.
Resulting process	Tentative and stepwise generation of design. Involves a high level of engagement with the design space. Could involve indirect application of parameters.	Transforming material (mirror effect) Discovering global patterns. Discovering local patterns.	Understanding real-life events and relations. Breaking preconceptions (schemata) discovering patterns.
Projects	Ambient Amplifiers especially Tøyengata.	Synthetic Landscape, Ambient Amplifiers, Conceptual Design	Conceptual Design, Designing Time.

Category	Real-life monitoring, parameter generation.	Direct modelling.	Sculpting with mouse and other input devices.
Technique	Time-collapsing and superimposing, Time-scaling, Time-sections Reversing, "scratching", "sampling".	Manipulation of CV's: Dragging, rotating, scaling of one or groups of CVs.	Sculpting with dynamic cursors on surfaces or with special force feedback devices.
Source material	Video registration.	Primitive geometry.	Primitive geometry.
Processing	Video monitoring and editing.	Manual geometrical manipulation.	Sculpting the surfaces in a similar way as a craftsman sculpts traditional materials.
Tools	Video editing systems Premier, Ifinish, After Effects, Flash.	Spline-based surface modelling software (Rhino, Alias). GUI and mouse-based displacement of CV.	Sculpt-tool Maya sculpting, Freeform Scanning software.
Resulting process	Understanding real-life events and relations. Breaking preconceptions (schemata) discovering patterns.	Work-process close to traditional design work.	Work process that is similar to traditional sculpting processes with physical materials like clay modelling or wood carving.
Projects	Conceptual design, Deigning Time.	Numerous small design projects, e.g. Small Formations.	Small Formations

Category	Parametric design.	Animation based parametric design, simulation.	Interactive simulation.
Technique	Altering constraints and parameters. Scripting own software. Programming in Proce55ing.	Enter start conditions, run simulation. Visualisation of results.	Interact in real-time with simulation of real-life situations
Source material	Parametric engine set-up.	Site material or principal start conditions.	Work process set-up.
Processing	Altering the parameters.	Simulation	Interactive simulation.
Tools	Parametric CAD software, other software. Proce55ing.	Simulation software CATIA modules, FEM analysis urban simulation etc. scientific simulation and visualisation software Weather forecast.	IFE virtual work process simulation. CATIA virtual ergonomics, flight simulators, games.
Resulting process	Models that allow for easy changing within the logics of the parameters. Investigation of many instances, complex relations.	Models that predict real-life behaviour. Models can inform design process.	Models that allow for training in real-life situations, entertainment. Can inform design processes.
Projects	ENØK, ASTRA (**Figure 2**) Motion Graphics in IT-Master.	VIZ scientific visualisation tool. Form Finding Module IT-master.	IFE collaborative work process with Create software and VRML simulation in nuclear reactors. Augmented reality research @ AHO.

Category	Cellular automata, genetic algorithms.	Data recoding mapping of 2D to 3D space.	Data recoding between different representations.
Technique	Scripting, modulating. Finding and investigating instances between start and end conditions.	Colour separation blurring and contrasting. Displacement mapping. Polygon modelling and export to STL.	E.g.: Translating spatial information into sound representation. And vice versa. Synchronising physical spatial features with auditive spatial features.
Source material	Genetic Algorithm start conditions.	Graphic img 2D	Any digital data set.
Processing	Running the algorithm in several generations.	Mapping (bump mapping, displacement mapping).	Transflation of data, recoding.
Tools	e.g. Gener8	2D and 3D software.	ASSCI format and other generic data representations. Scripting translation of data.
Resulting process	Models that can be applied in self-growing designs and as creative input.	Production of spatial organisers that depart form Cartesian grid "Disturbing Agents", breaking schemata, creative input to generation of 3D spaces.	Investigating structural features in different media. Creating related output in different forms.
Projects	Jewellery, speaker and key-ring in IT-master classes.	Synthetic Landscape, VORB, high def texturing and rapid prototyping, experiment with glass casting, a_drift and World Center RP-models.	Tidsrom, AGORA

Category	Animation -based technique. Particle animations.	Animation -based technique. Skeleton animations.	Animation -based technique. Dynamics.
Technique	Setting up particles forces and movements according to abstract structural intentions.	Setting up skeleton structure assembling relations. Animating skeleton according to chosen principle.	Setting up framing space, dynamic cursors, forces, environment and surface features. Introducing precise but subtle control mechanisms.
Source material	Source material is animations set-up. The resulting output is used as source material for further design process.	Source material is animations set-up. The resulting output is used as source material for further design process.	The source material is animation set-up. The resulting output is used as source material for further design process.
Processing	Running animations and fine-tuning the set-up to achieve a desired result. Selection of runs and instances according to selection strategies and guidelines.	Deformation of geometries driven by skeleton kinetics.	Running of the animations results in the configuration of dynamic spaces or the deformation of geometries driven by dynamic cursors.
Tools	Alias Studio, Maya, 3DSMax.	Alias Studio, Maya, 3DSMax.	Alias Studio, Maya, 3DSMax.
Resulting process	Spatial organisers that depart form Cartesian grid Input for spatial distribution and field conditions.	Spatial organisers most suited for small and medium scale objects. Negotiation of body-scaled spaces and forces.	Spatial organisers and forms which are suited for prerationalization through the design of framing space, controlling devices and forces.
Projects	Synthetic Landscape, Chamberworks.	a_drift	High Rise Study. World Centre for Human Concerns.

4.3.6. Examples of techniques

The complete material which was the basis for this analysis is too vast to be presented within the frames of this thesis. Some of the techniques like recoding and grafting have already been described earlier. Therefore I will present two samples very briefly. In the next section (4.4. The further use of the generated material), further use and strategies for preparation and realisation will be presented. In this section, several techniques will be described further and related to the concepts of templating and scaffolding. This section together with the discussions in part 3 and part 5 will provide a deeper picture of the techniques.

The two selected techniques are:
- Sculpting
- Animation-based techniques

These two samples together with the earlier described concepts of recoding, translation, generative diagramming and grafting provide a cross section, from manual direct forming via scripting and programming to explicit generative animation-based design. This cross section covers the main aspects of the field while (give number) and part 5 draw a more complete map.

Example 1: sculpting

The most direct way of designing on the computer is to sculpt the geometries that represent the final product. Artists and designers work with a computer system in a similar way to how they would work in a physical material.[110] This corresponds to the category 'explicit modelling' frequently used in CAD systems. It is also normally referred to as surface modelling but in this case it is a very developed form of surface modelling where an "intelligent" virtual tool is used to deform the surfaces.

Sculpting on the computer has other constraints than sculpting in physical material. In the same way as each material has different attributes, digital modelling techniques have limitations and possibilities which will influence the final output. These constraints are related to the mathematical representation and the interface of the computer.

Advanced sculpting techniques apply some kind of artificial tool that makes the manipulation of the geometries more intuitive and easy. The geometries are represented either in polygons or in spline surfaces. The spline surfaces allow for a high degree of control of smoothness and continuity.

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[110] It is relevant to remind of Malcolm McCulloch's exploration into computing as a modern craft similar to the traditional ones based on trained skills, intuition and tacit knowledge (McCullough, 1996)

Also relatively sharp edges are easy to insert by increasing the number of controlling isoparms. Spline surfaces allow direct manipulation of the control vertices while maintaining a complex and smooth surface, due to the low number of control vertices. Splines surfaces are defined with a two-directional network of U and V isoparms. This is a disadvantage when we are sculpting areas of a geometry where two surfaces meet or where surface edges shrink (like in poles of a sphere). It is also difficult to sculpt diagonally across the direction of the u and v isoparms. This is normally solved by dividing the geometries into surface patches where each patch is structured so that they fit the geometries. But this constitutes new problems since the edges between adjacent surface patches are hard to control thus making it difficult to maintain continuity between the patches. Sculpting therefore is most successful when it is possible to work with singular surfaces where the isoparms are oriented so that they match the overall topography of the object. [111]
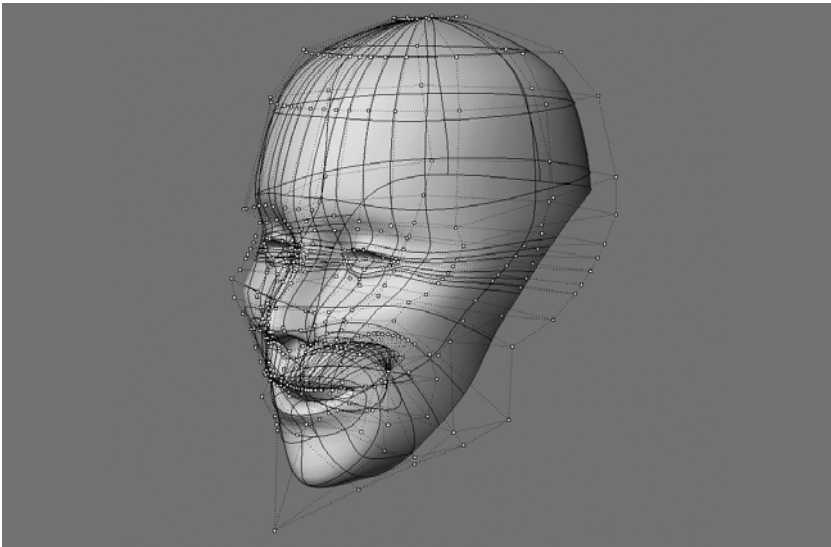
Figure 76   Splines with relatively few control vertices. The density of isoparms (the lines on the surface) and related control vertices (white points) varies according to local topological variations. Areas with small-scale details (like eyes) demand for higher density of information, hence the distance between the isoparms is shorter. (Sample from Rhino3D)

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[111] Splines geometies have become highly appreciated and advocated by architects such as Greg Lynn (Lynn, 1999). The smooth and economic representation of curves has partly overshadowed its disadvantages which have caused other industries like the gaming industry to reject the use of splines.

Polygons are more homogenous than splines since they do not have a U and V coordinate system. Polygons are therefore geometrically neutral as long as the number of polygons is large enough to approximate the details of the geometry. But a high number of polygons makes direct manipulation of singular control vertices impractical. In cases where a very low number of polygons is acceptable or desirable (as in game design) the singular manipulation of polygon vertices is feasible. But with the recent development towards ever more complex models, even in game design, the days of manipulating polygons directly are numbered. With a very low number of polygons the neutrality of the geometry is reduced. A large degree of freedom in manipulation implies a huge number of polygons which easily brings the computer system to its limits. This is especially unfortunate since direct manipulation is dependent on real-time feedback and an immersive environment.

Sculpting splines surfaces is easy because continuity is inherent in the mathematics of the splines and because they are defined with very few control vertices. Sculpting of polygons is normally dependent on the use of special sculpting tools in the software that allow for manipulating areas of the polygonal surface in a smooth and controlled way, calculating continuity across the polygonal surface.

High-level sculpting tools create a layer of virtual tools between the mathematical representations of the geometries and the user. We become less dependent on the understanding of the mathematic library and the manipulation skills are supported with "intelligent" manipulation concepts. Future design work will probably increase the distance to the mathematical representation. CV manipulation of splines has already almost disappeared. The CVs are hidden in the default setting of the latest versions of the high-end modelling software Alias Studio. The future of computer-aided modelling is not in the invention of new geometrical representations but in the invention and development of intelligent modelling tools that are capable of interpreting our intentions.
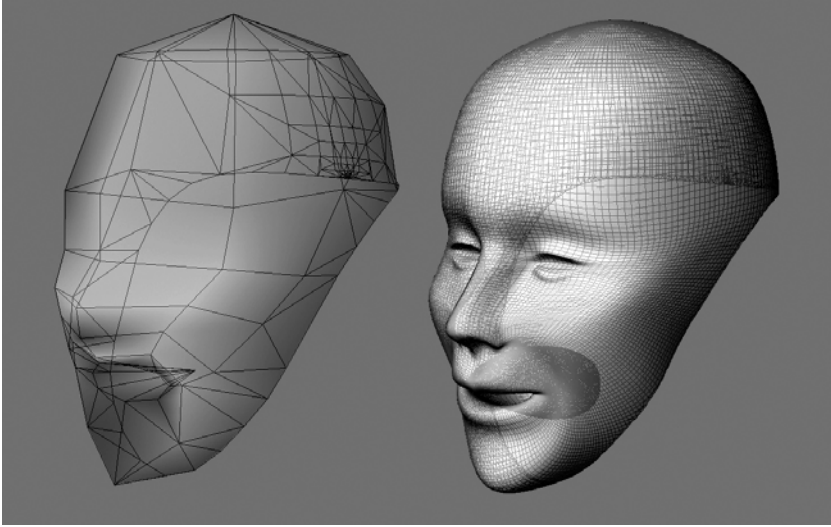
Figure 77 Polygonal representation. Polygons approximate smooth continuous surfaces. More polygons render a closer approximation. Direct manipulation is possible with very few polygons (left) but very laborious with many (right)

Case: Generic Containers "Small Formations"
This case has been chosen because it demonstrates a mixture of modelling techniques with a physical output. The physical output allows for a particularly close evaluation of the results.

> **Small Formations**
> Experimental generic containers.
> Part of "Formations" installation at Fondatione Nicola Trussardi in Milan
> 2002 by OCEAN NORTH
> Birger Sevaldson

"Small Formations" is a series of spontaneously formed hollow objects with no assigned specific functionality. The objects where designed in several stages:

1. A rotated surface which already has the main contours, volume and topology of the final product.
2. Deformation of the symmetric rotated surface by dragging CV's and groups of CV's.
3. Splitting of the surfaces to introduce ruptures.

4. Sculpting of details and further deformations with the sculpting tool in *Maya*.

5. On some surfaces a pattern was created with displacement mapping.

6. Offsetting to create surface thickness.

7. Closing of surface edges between the original surface and offset surface.

8. Export and repair of STL files and RP-production in SLS machine.

The Maya sculpting tool was used with mouse as input device. This is not ideal and a pen pad (e.g. Wacom) has advantages regarding the level of control. A pressure sensitive pen also allows direct control of the cursor radius or depth of the manipulation. The sculpting process was important in this project even if it was only one of several techniques. It introduced the most characteristic form elements in the design.
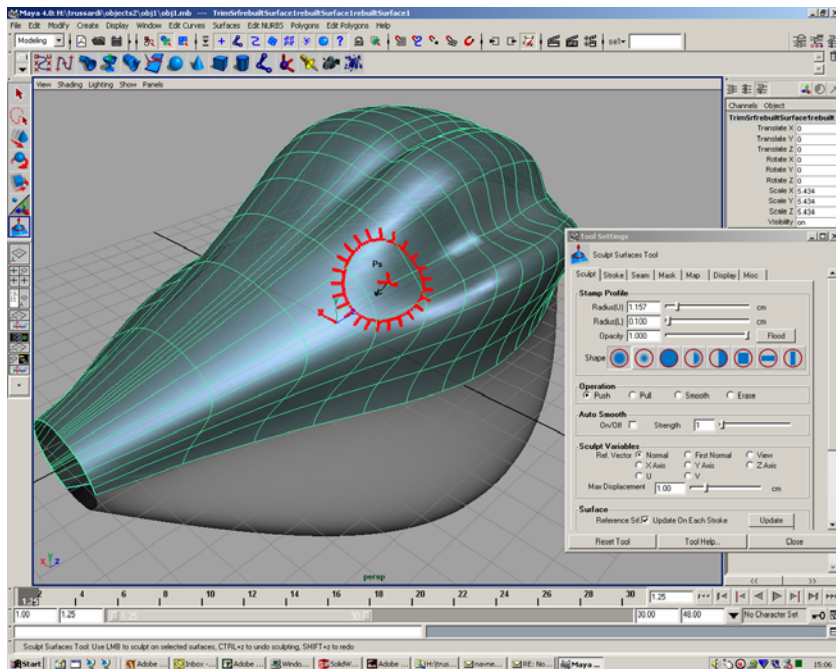
Figure 78 The sculpting tool in Maya has a cursor that follows the surface. The cursor has a long range of options to pull, push and smoothen the surface including diameter, shape and pressure.
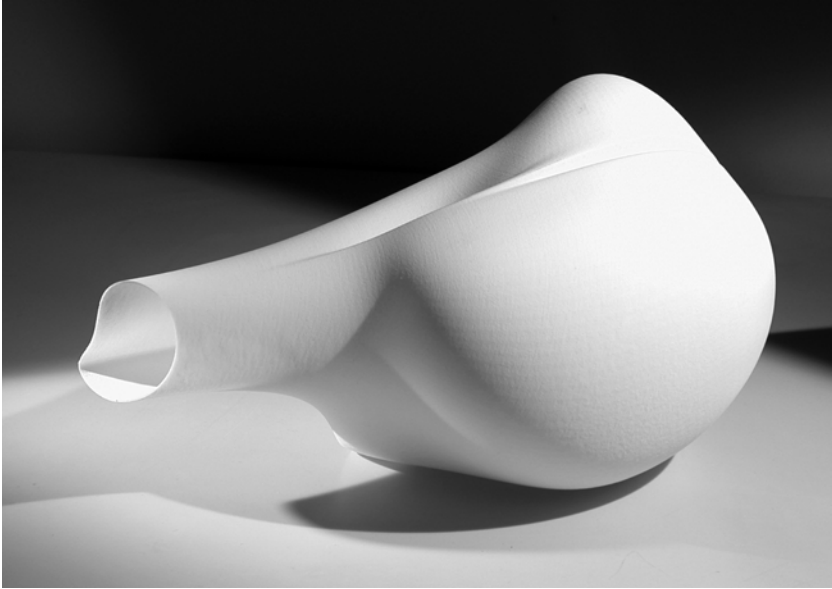
Figure 79 One of the final objects.
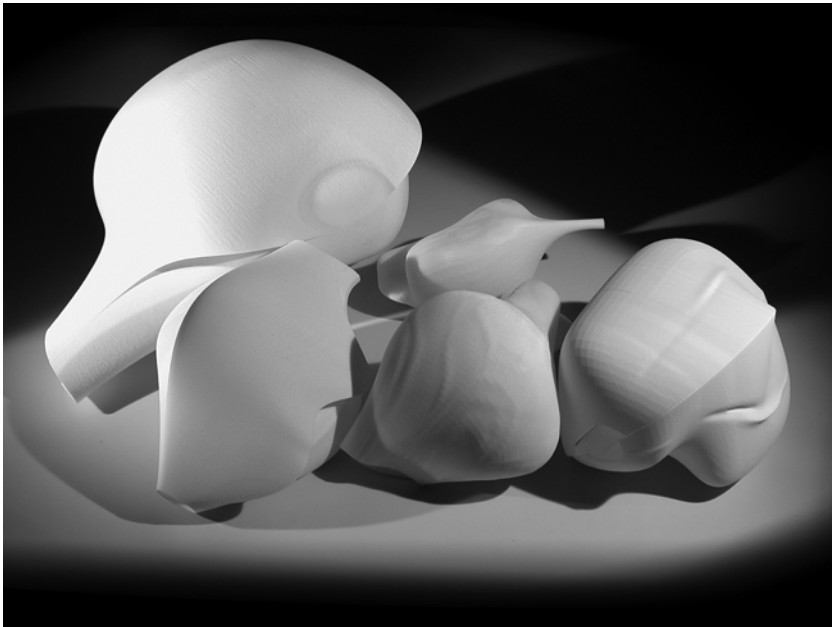
Figure 80 Collection of objects.

Example 2: Animation-based techniques

Description of technique

In animation-based techniques, we use animation software for design purposes. The motivation is at least twofold:

- Animations are the most accessible tools for designers who are not programmers to work with generative design techniques. Animation tools are accessible in many off-the-shelf software suites and they have intuitive interfaces. Also some of them are very advanced allowing implementation of a long range of parameters and even scripting.
- Secondly, animations are attractive to designers because they can be used for time-based design techniques with which we can analyse and respond to dynamic systems and events. Visualisation, simulations and generative speculations with the help of animations are starting to become widely appreciated amongst designers.

Animations have also the advantage that the output is easy accessible. We can export geometries from any frame of a transformation and we can create video footage which allows for video-based analysis such as selecting sections in time, collapsing or expanding time, or reversing and "scratching"[112].

In the use of animations as generative design tools, we can involve a wide range of parameters that may represent abstract or concrete forces that unfold during a chosen time span. Each parameter can be animated. In this way, it is easy to create an animation set-up that triggers an autonomous process where the output is too complex to foresee. This results in a simple emergent machine.

Dynamics are common tools in animation software for the simulation of objects in real environments where forces like gravitation, wind, friction and collision will influence the behaviour of physical objects. These tools are designed to make objects behave as expected. But we can use them as generative tools when we consider the forces to be abstract forces rather than simulating real-world object behaviour.

The results from the animations could be used as templates or scaffolds for form generation and design or to inform generative programs.

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[112] Scratching is an analysing technique I developed for the finding of virtual phenomena or extraordinary events in a generative animation. Repeatedly moving the cursor back and forth in the timeline of a video editing tool resulting in a real time play of a short section of a video in forward and backward motion reveals details and patterns in the video material.

A Case: The World Centre for Human Concerns

This case we return to the World Center described in the introduction. The example demonstrates an advanced animation-based technique where several levels of abstraction are integrated. The animation is designed within a design space that is organised according to existing conditions and design parameters. The design space is an abstract tuning device to adjust the animation.

In 2000, OCEAN NORTH was invited to contribute to the exhibition at the Max Protetch Gallery in New York featuring proposals for a new World Trade Centre.[113]

Our contribution was designed on the basis of a generative animation driven by dynamics in the software MAYA by ALIAS. Our concept involved the wrapping of two new skins around a space defined by the local conditions and by the volumes of the former WTC. In our cooperation over distance I had the task of producing the initial animations to be delivered to the project team in London[114] as an underlay for the design. I wanted to create an output that was at the same time controlled and "wild"– one that lived its own life. The type of geometries I searched for were surfaces with relatively smooth articulation. The degree of "kinks" was smaller than in the preceding high-rise study (Figure 85). Therefore the weighting of control vertices was not used. I used two surfaces which was stated as part of the concept brief but which also creates more distinct surface geometries. The use of two or more surfaces constitutes the distinctive and accurate intersections that provide for more accurate local articulation of spaces and the division of the inside into a system of internal spaces that later could inform the programming and inhabitation of the space. The use of one surface only still results in intersections (self-intersection) but the complexity of the resulting space needed to be greater than what would be the result if using only one surface.

I constructed an engine of a relatively large number of spheres that were used as cursors to deform the CVs of two initial surfaces. The spheres were captured in a vertical space, horizontally sectioned with deformed polygonal surfaces, the "input surfaces". These surfaces where used as tuning devices to regulate the degree of "wildness" in the output. Also the volumes of the former WTC where inserted as spatial limitations and I introduced an outer

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[113] OCEAN NORTH's project "World Centre for Human Concerns" was commissioned by the Max Protetch Gallery, New York, with 50 other architects and designers to create a visual comment on the future rebuilding of Ground Zero. The result was exhibited at the gallery and numerous other places and has been widely published since its release in December 1999 (Protetch, 2002). For more information on the project go to www.ocean-north.net.

[114] Michael Hensel, Achim Menges, Morten Gregersen, Lip-Khoon Chiong.

limitation within which the spheres were allowed to move. The spheres were activated by gravitation and wind forces in the software, but these forces represented abstract and undefined virtual dynamics operating within the design space. They did not correspond to any real forces on the site. In this set-up they where thought of as abstract triggering forces which informed the design space in a similar way to any other initial structuring of space such as the use of axes in a building. The spheres were modulated to bounce off the input surfaces in a way that would keep them moving as long as the animation was running. The animation spanning from frame 0 to 500 was stopped every 10 frames and a 3D model of the surfaces was exported. These geometries informed the later stages of the design.
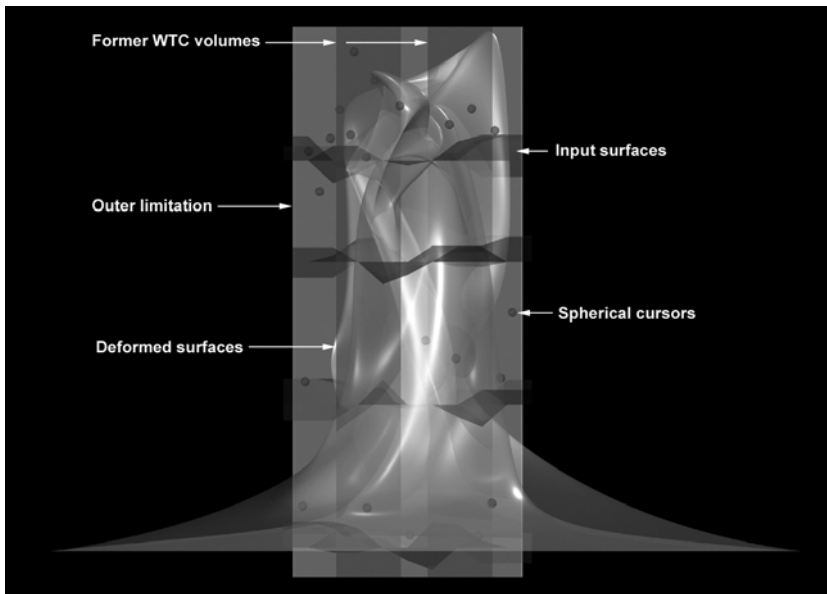
Figure 81 Side view of the dynamics set-up showing the different elements involved. The image shows a stop-frame after the animation has been run for a while. The two template surfaces have already been deformed and we can see the contours of a sketch for the new World Centre.

This approach implements a very accurate control mechanism into a generative design engine that normally produces "wild" and unexpected output. By modulating the input surfaces it was possible to monitor the degree of deformation during the animation. Also, the layered design of the set-up made it possible to have local variations. The engine was an attempt to

combine the generative self-emerging design machine with very precise control mechanisms. It is a game of losing and gaining control.

This experiment was successful in the sense that it produced a design template that was rich enough and inspiring for the design team to work with. (Figure 82) But the control mechanisms did not really result in very big variations when altered and there is a potential to further develop other "taming" mechanisms.
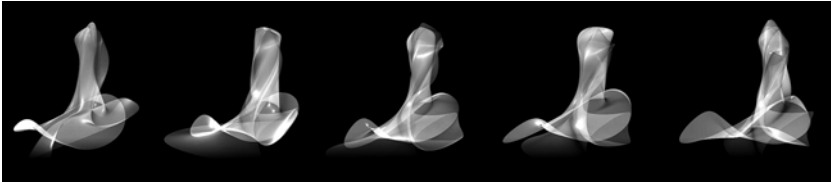

Figure 82 A selection of evenly-spaced frames from the resulting animation. The topological deformation of the surfaces ensures a consistency between the samples while providing a very rich variety of emergent shapes. While maintaining the global dimensions and layout, the variation in both surface form and details is very rich and provides a good template for the further design process.

In an earlier experiment for a high-rise building more local variation was achieved by altering the weight of the CV's in local areas. This setup divided the design space into areas of varying intensity. (Figure 83) The design intentions suggested a varied articulation and smooth transition from the horizontal surrounding city fabric towards and throughout the vertical organisation of the high-rise structure. The deformation of an initial skin into a large variation of alternatives was monitored by several elements and parameters. I used *dynamics* in the *Alias Studio* Software as the main deformation tools. Deformation cursors, small spherical bodies, where dropped onto deformed polygonal surfaces from which they bounced off within a limited cubical space. The shape of the intensity surfaces (similar to the input surfaces in the World Center project), the virtual elasticity of the intensity-surfaces, the cursor-spheres, and the surrounding limiting walls together with simulated friction were the parameters that were used to tune the engine. With these means it was possible to create a variation of articulations along the vertical structure. Three intertwining surfaces where used simultaneously. This produced a less clear separation of spaces and prepared for the following negotiation between interior and exterior via diverse climatic zones.
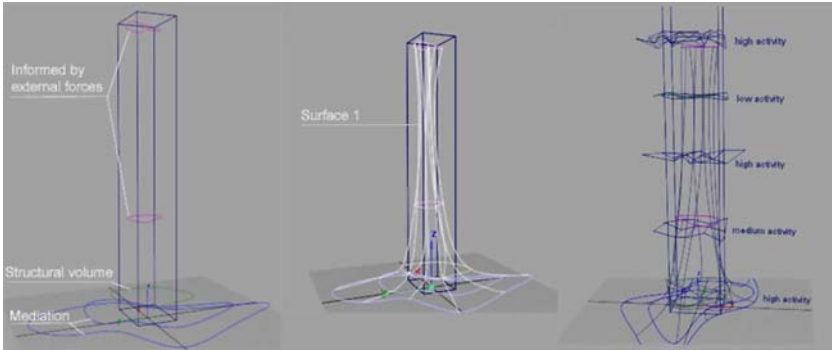
Figure 83 The generative animation set up for the high- rise study. Left showing the design space limitation that keeps the bouncing ball cursors inside the design space and the input surfaces that conceptually were informed by imagined external forces. In the middle: one of three design surfaces before deformation. To the right the input surfaces showing the different levels of varying activity.
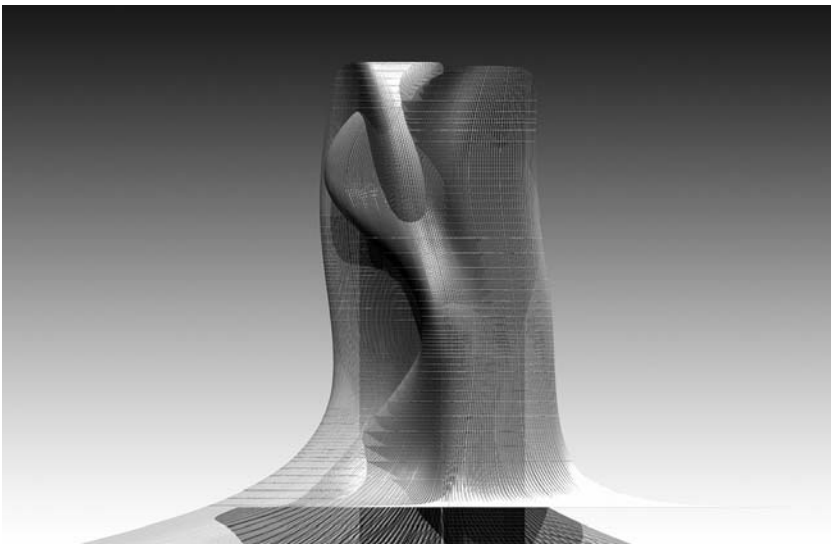
Figure 84 Side view of final suggestion for a new World Center for Human Concerns (rendering and design by London project team, OCEAN NORTH
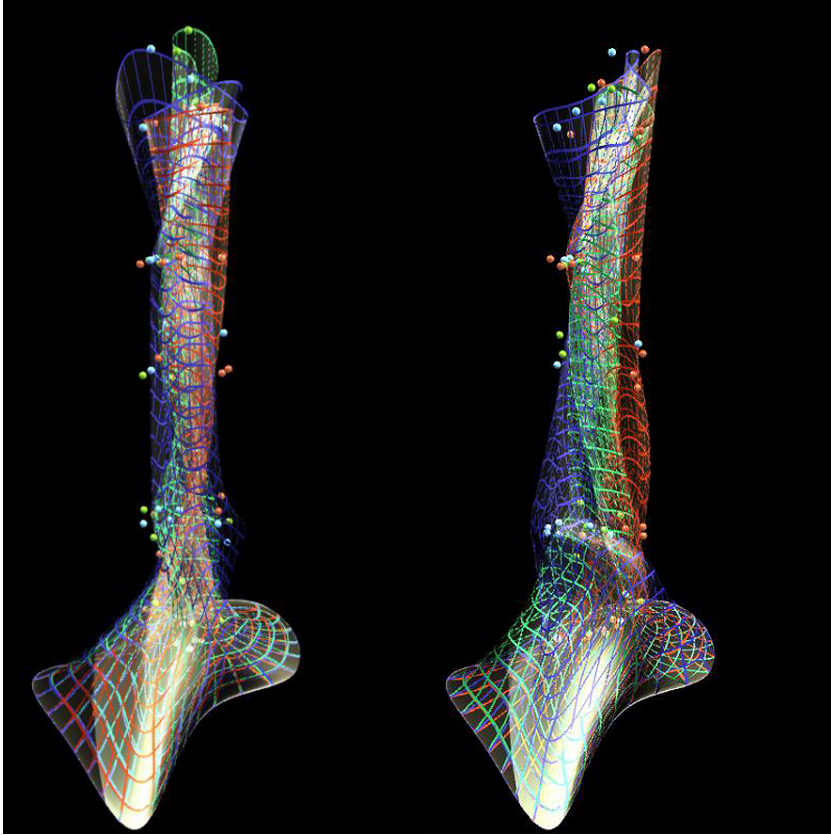
Figure 85 The image shows one stop frame of the final animation for the High-Rise study. Three surfaces were involved each with its own set of bouncing ball cursors. The surfaces were rendered transparent and with a grid surface to show the interesting local spatial relations that emerged in the animation.

To achieve a real differentiation between the levels, several parameters were tuned to modify the intensity of the deformation. The flatter intensity surfaces were used in the low activity levels. In addition the bouncing parameter for the surfaces was much lower in the low activity levels and the CV's in the high activity levels where given a greater influence on the design by increasing their weight (a typical NURBS feature)

Some of the features in the High-Rise study were lost in the following World Center project which resulted in a simpler and smoother design. The advantage with the World Center set-up was that this design was easier to work with and to develop further into a final design suggestion. (Figure 84, Figure 86)

Figure 86 Rapid Form RP model of final solution. This is probably the first architectural model in this Steel / Bronze alloy rapid prototyping material from 3DSystems.The surface patterning indicating a façade design was made with displacement mapping challenging the borders of what was possible when it comes to the capacities of geometric construction and computational capacity.

4.3.7. Traces of technology.

Numerical controlled (NC) technology for physical output and production offers a great amount of form-freedom and accuracy, but it also has inherent emergent qualities.
Rapid Prototyping technologies are especially important in the early phases of the process. The excitement of experiencing a complex model in real life after only being able to examine it on a flat screen is enlightening.

The processes add their trace to the output. CNC-milling leaves tracks of the milling tools. The tracks are generated according to milling concepts and parameters. RP-technology also creates traces of how the objects were built. The layered production leaves "topo-curves" on the surface of SLS-models. Digital production methods tend to induce a textural treatment of the surface. We tried to exploit this emergent surface texture both in early milling exercises and RP models where we combined the effects with ornamental treatment of the surfaces through displacement mapping techniques. Another source of potential exploitation of surface articulation effects inherent in the digital controlled production of physical models is found in Greg Lynn´s use of CNC technology (Leach, 2004).

I started conducting milling experiments in 1993. The robotic technology is fascinating but not very accessible. In the beginning I used a small Roland CNC router exclusively for the production of representative models, except in a few cases where I experimented with spontaneous use of the CNC-router. I started to investigate the generative use of this technology in 1997 with the construction of a surface installation that was shown at the Hennie Onstad Museum in 1997 and in the AA Gallery in 1998. (Figure 87) The traces from the grinding tool where essential in the result. Their beauty and intriguing exactness triggered several tests with vacuum moulding of opaque and transparent acrylic plates. Especially the transparent samples held together with the ground blocks created some very beautiful effects of surface depth.
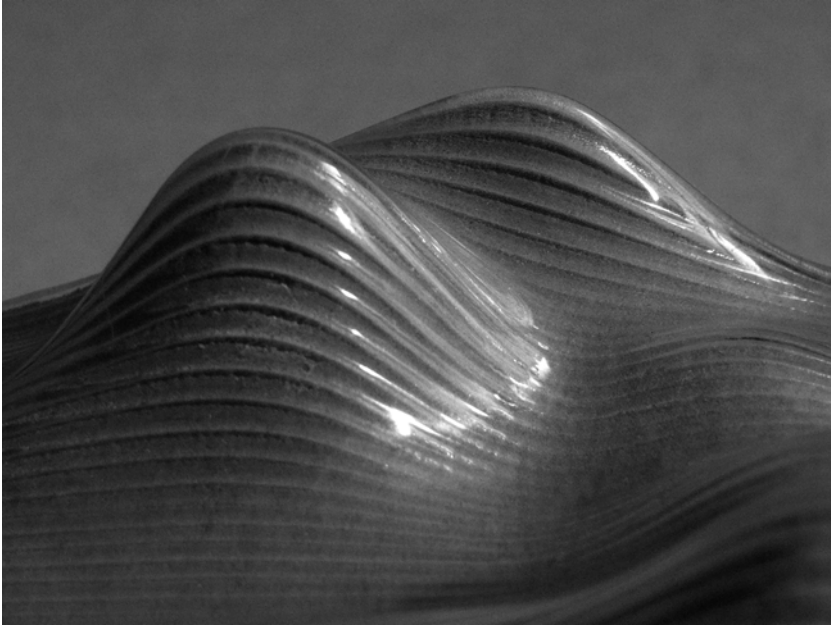
Figure 87 The traces of parallel tool paths on a Cibatool ™ block that was later covered with a transparent vacuum moulded acryl plate. (Birger Sevaldson 1997)

In a later experiment I used more complex surfaces and a much finer grinding tool with a diameter of only one millimetre. The result is a physical model that is unique because it is hard to imagine any other way of producing the surface articulation and effects it produced. The models were regarded as 3D diagrams of diagrammatic information surfaces (from the Synthetic Landscape project) that until then only were visible on a 2D screen. The physical model contributed to the reading of the surfaces and the added tool paths added local articulation to the surface.
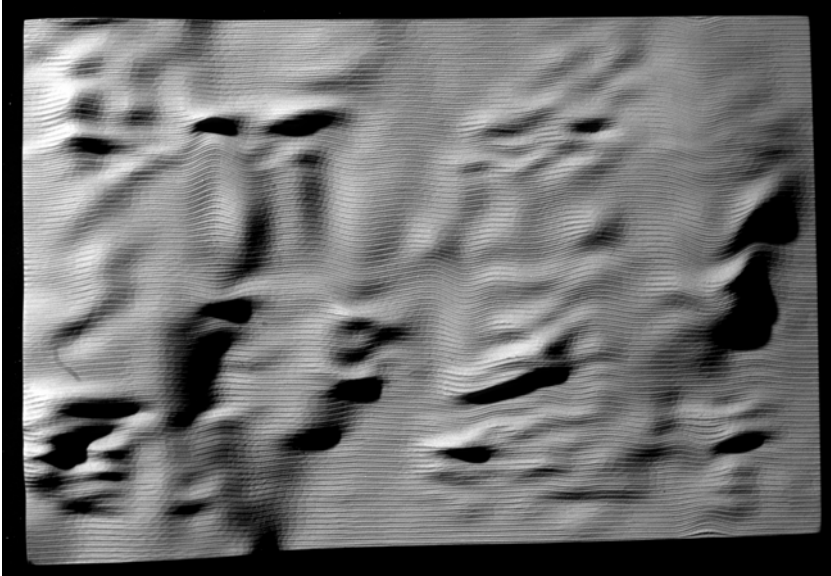
Figure 88 Very fine tooling paths constant parameter milling for surface articulation. This is a three dimensional physical diagram where the production technology is used consciously to add articulation to the information surface that was used as the model for the CNC- process. (Birger Sevaldson 1998)

RP technologies also add articulation to the surfaces especially the SLS technology we use at AHO. I never avoided these patterns but regarded them as additional emergent features of digital production. To a certain degree these patterns are controllable by altering the placement of the models in the built. Especially surfaces that have a slightly tilted direction relevant to the horizontal build plane produce clear patterns (Figure 89).

Figure 89 Emergent surface articulation from SLS production process. Synthetic Pavilion (Birger Sevaldson et al, 1997) This model was so complex that it was hard to understand on the screen only and the physical RP-model was necessary to investigate the emergent space fully. Polygonal file and the Selective Laser Sintering (SLS) left a pattern of surface articulation. The layers from the sintering produced a beautiful line pattern and the facets from the STL export file are barely visible as a secondary articulation.

In 1999 I started to experiment with adding additional patterns to the surfaces. The technique I used was displacement mapping. The first sample was the "a_drift" time capsule where the surface was articulated with a rendering from the inner core. (Figure 98) The first experiments were quite crude and the balance between surface and pattern was finely-tuned over several steps. The biggest difficulties were to close the polygonal geometries resulting from the displacement calculations so that the RP-system would be able to use the geometries for production.
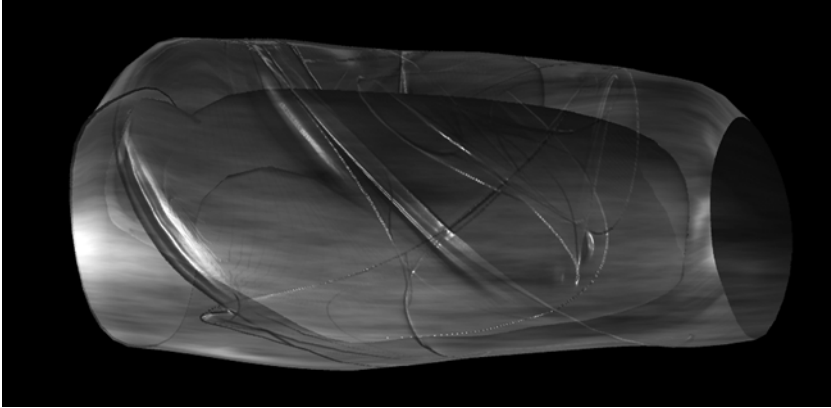
Figure 90 First crude test of the displacement mapping of a surface. (a_drift 1999)
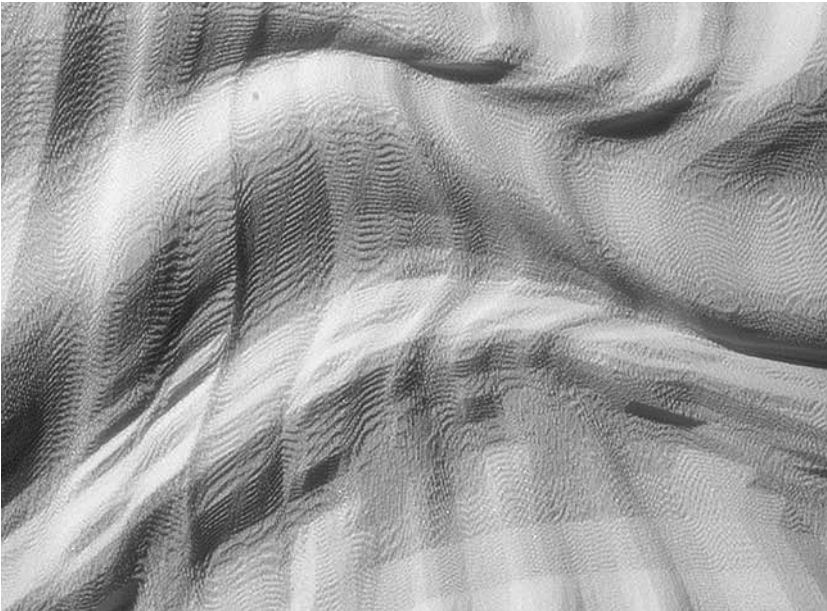
Figure 91 Experiment with the combination of emergent articulation from the SLS-production process and induced articulation through displacement mapping. The very small patterns emerge from layering in the RP-technology. They are most visible in the upper left. The vertical patterns and horizontal folds most visible in the lower right are patterns created by displacement mapping techniques. The biggest scale wave-forms are geometrical features of the original surface. The intent of this experiment was to produce a seamless blending of these three scales and sources of surface articulation. (Birger Sevaldson, Michael Hensel 2001)
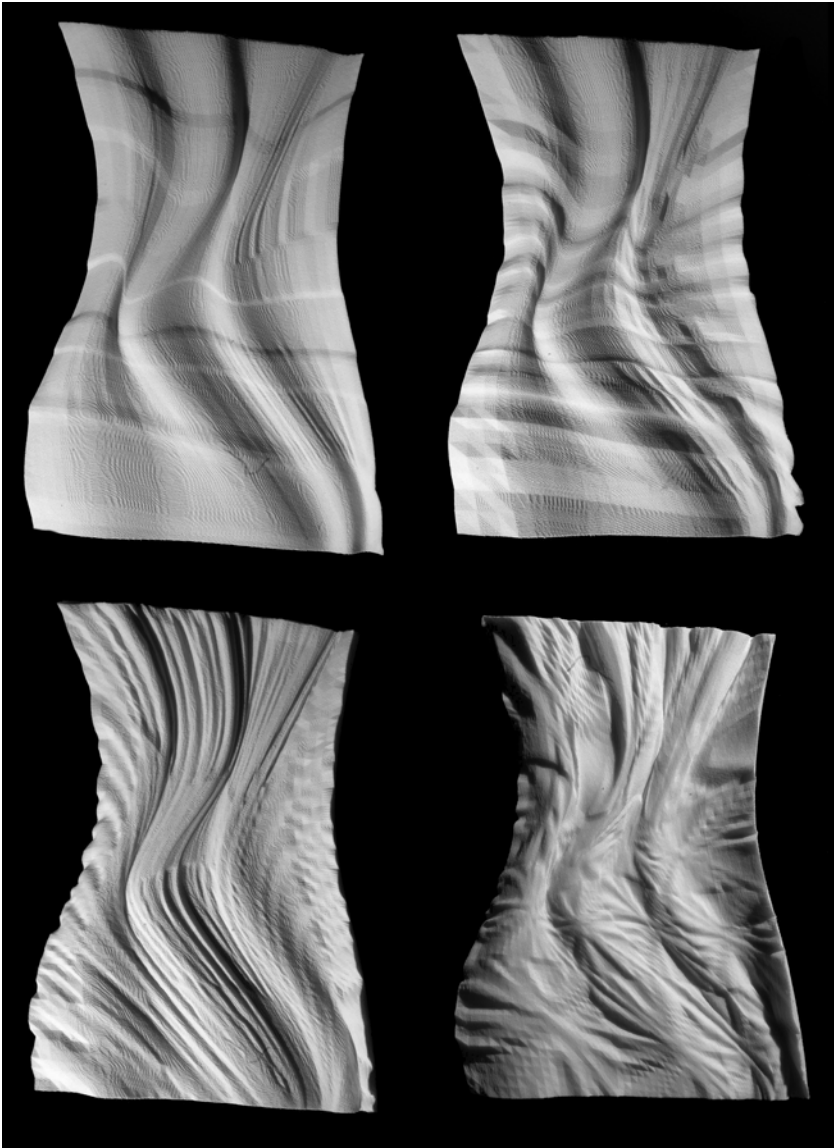
Figure 92 Rapid prototyping models of different tests with patterning with displacement mapping.
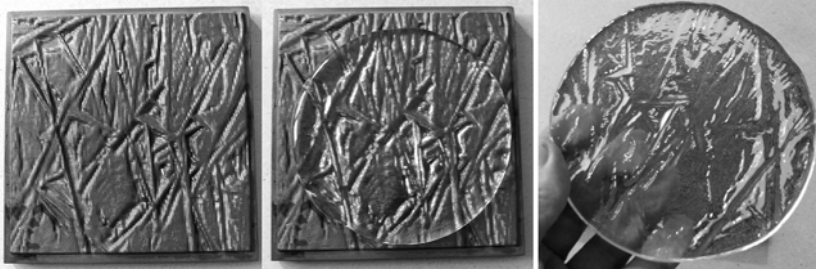
Figure 93 Displacement mapping of crystal pattern produced in Rapid Form ™ to use it as a mould for glass casting. To the left: The steel bronze alloy mold, Middle: the glass test on the mold. To the right: the glass test. (Birger Sevaldson, student Lena Hansson, in cooperation with Hadeland Glassverk 2003)

These experiments clarify a very important and central aspect of working with computerised modelling techniques in particular but also with computers in a creative process in general. To exploit the technology we need to be both insistent and flexible. We need to be quite stubborn and have the stamina to achieve what we want. In the samples above, many errors and a lot of work went into the production of the geometries. The production of STL files for the RP-system was very tricky in the beginning. Now the software has improved and things are easier. But whenever we want to explore and expand the use of computer technology a considerable amount of time must be spent on errors and experimentation.

On the other hand, we need to work alongside the technology with a good portion of opportunism. In this case it includes the exploitation of the pattern generation inherent in the technology instead of trying to resist these effects.

4.4. THE FURTHER USE OF THE GENERATED MATERIAL

In this section I will try to outline some strategies and ideas of how a design process that is jump-started with a generative phase could continue towards realisation. This leads to a discussion of representation and of translation and processing of the initial material towards the final design.

Robin Evans points to the distinction between the role of the architectural drawing and the sketch for a painter or sculptor. (Evans, 1997) The purpose of the artist's sketch is:

> ...to give sufficient definition for final work to begin, not to provide complete determination in advance, as in architectural drawing. (Evans, 1997)

This final work is far from final in the sense of it being a last phase of a longer process but it is final in the sense that it represents the "thing itself" and not any abstract or diagrammatical representation of how it operates or is structurally organised:

> ...painters and sculptors, who might spend some time on preliminary sketches and maquettes all ended up working on the thing itself which, naturally absorbed most of their attention and effort. (: 156)

Architectural design implies a deeper consideration of what the drawing represents, than is the case when *working on the thing itself*. Both or all possible perspectives can be used when we work with generative digital material in a similar way as in traditional design. But our considerations and strategies will change a little.

Only very seldom is the generative material used as a drawing from which to build exactly as described. Another question is if this is at all possible. Any translation of the design sketch into a new representation, be it another digital drawing, a physical model or a finally built product will involve big changes. But this is not only the case for generative design processes, although it is more evident in a process that starts with less control than in a "normal" process.

Robin Evans describes the idea of a translation from drawing to building without altering the design as a delusion. He calls for *critical disbelief* towards the drawing and states that in architecture there is a peculiar misinterpretation of the drawing's role in the design process:

> …a curious situation has come to pass in which, while on the one hand the drawing might be vastly overvalued, on the other the **properties** of drawing- its peculiar power in relation to its putative subject, the building- are hardly recognised at all. Recognition of the drawing's power as a medium turns out, unexpectedly, to be recognition of the drawing's distinctness from and unlikeness to the thing that is represented…. (Evans, 1997)

If this is true for the traditional process, it is even more evident in the generative design process where the drawing, diagram or virtual model has a more powerful and distinct role than is otherwise the case. The translation from generative material to final design is longer and involves a greater

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degree of change. Therefore we need to address this phase of the process in particular.

4.4.1. Realisation strategies

The further use of the material is dependent on the level of materialisation. If we state that the end is to build the design in physical form, we can go towards realisation according to pre- and post rationalisation[115] strategies. These considerations can be implemented in various ways but in this case I will suggest some specific ways of regarding the material on different levels of distinctness from the final design. The levels introduce a possibility to move towards a final solution in small steps where the generative diagram (negative agent) and the design intentionality can be negotiated in a smooth process.

Pre-rationalisation strategies

We can build considerations into the generative engines from the start. These can include: main structural organisation principles, material technology and social behaviour and relations to surrounding environments.

The way forward to realisation can be built into the process as a strategy already from the beginning. When working in the traditional way, I often consider materials and technology from the very start, keeping these issues in the back of my mind. The simple strategy is to avoid developing the design in a direction that would be very difficult to build. Frequently during the process I question the probability of being able to solve the technological challenges that I know I will meet later. The knowledge of how to construct is part of the background knowledge of the architect or industrial designer. This knowledge is both tacit and explicit. It restrains the design process from an early stage. I would already during the sketching phase consider the probability of being able to solve the problems of draft angles in the particular design. I would not solve these problems at this stage but judge the difficulties I might run into later. These considerations might stand in the way of innovation. They might lead the process along known routes especially when the realisation pressure is high and risk calculation is important.

Generative design techniques often disregard such considerations and leave problems of realisation to later stages. Negotiation takes place between the designs, aiming for realisation at a later stage. But the generative process gains greatly from different pre-rationalisation strategies. Pre-rationalisation

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[115] Mark Goulthorpe refers to pre and post rationalization in his and Mark Burry's conceptual project Paramorph (Goulthorpe, 2004)

would lead a generative process along a route that would ensure a potential realisation and the elimination of potential translational difficulties throughout the design phases. The incorporation of geometric constraints into the very early stages of the design process will delimit types of ranges in a useful way, while still enabling the production of largely non-anticipatable design outputs. This is a development of the generative design process which has been investigated by for example The Architectural Association Emergent Technologies MArch Programme (Michael Hensel)
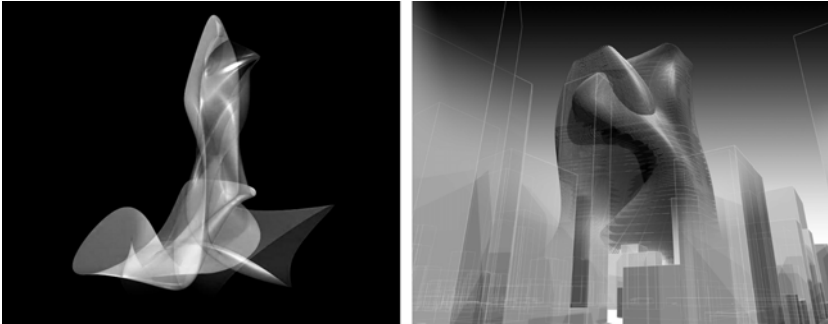
Figure 94 In the design of the World Centre for Human Concerns, the initial generative model integrated some of the considerations of realization while others where left to be solved later. The connection to the surrounding structures and the organization and complexity of the vertical city were already integrated from the beginning, while the development of the template towards a building geometry was done later

Pre-rationalisation strategies involve our preconceptions of a potential design right from the start, building them into the generative engine. We speculate that the later refining and realisation phases will be smoother if we already relate the generative engine to certain considerations. The intention of this strategy is to balance the preconceptions with the unanticipated. At the end of this scale is parametric design where all drivers of the generative engine are derived from preconceptions of the forces that will modify the design. Other pre-rationalisation strategies involve the framing and layout of the design spaces, the incorporation of existing site features and forces and the incorporation of design intentions and generation of possible developments.

- Incorporation of geometric and material / technological constraints in the generative design setup

- Framing and layout of the design space.

- Incorporation of existing site conditions and forces in the design space.

- Incorporation of design intentions in the design space.

Post-rationalisation strategies:

- We need to find a material technology that allows us to build the generated forms
- We need to negotiate the forms to meet the requirements of the chosen material technology.

Finding material technologies for a generative design is a challenging task. We want to translate the forms and the effects created from the generative source material, often without any material constraints or considerations, into material form. Generative design processes in architecture contribute to a technology pull which makes building engineers stretch towards the development of new building technologies.

Basically there are two approaches to material technology, either the material and technological conditions and constraints are used as the starting point for design and a "language" of design is developed from the material conditions, or the design development starts from other considerations, social, cultural, media or generative design, and the means to realize the design are found later. The latter approach leads to a technology development where the engineers have to face and solve the challenges from the designer. Both approaches are feasible. They are just expressions of different approaches to design. A mix of the approaches is beneficial and should be investigated further in the relation to digital generative design.

The realisation of a generative design involves negotiation of the source material or the developed design to meet the requirements of the material technology. Finding a suitable way of building and negotiating the building design to meet the material requirements go hand in hand.

Post rationalisation implies modulation, refinement and in many cases simplification of the design.

4.4.2. Templates and scaffolds

Amongst important devices to implement pre-rationalisation strategies we find templating and scaffolding.

Computer-generated generative output used as underlay has a similar role to the early sketches in a traditional design process but there is a crucial

difference, because the negotiation of control is different in the hand sketch than in digital source material. In normal sketching techniques, we expect a development of the design. This development can be more or less direct. When using digital source material as templates, the demands on development are greater, mainly because, as mentioned earlier, there are often no or few pre-set parameters. The negotiation techniques must be developed further than is normally required in a traditional design process. Normally we use a larger amount of material and tentatively explore the possibilities, grafting and sampling, switching between different representations.

The generative engines are more distant and abstract and do not always represent the sketch for a potential design but operate on a diagrammatic level. We use the term scaffold rather than template if this is the case. Scaffolds are more loosely connected to the design and they imply translation strategies from the beginning.

The concept of scaffold relates to the envelope concept mentioned in the project 'Tidsrom' (Sevaldson, 1999b). While an envelope is more an event-based device that would embrace the geometry of a time-based change, the scaffold is more about structuring the space of the envelope.

Thomas Leerberg introduces the concept of Design Space in his thesis of 2004 (Leerberg, 2004). He argues that the animations of Greg Lynn are rather to be seen as a design of *design space* than attempts to design a building and compares this with Schindler's unit system (p. 230- 231). Whether or not this is a correct interpretation of Greg Lynn's work is less interesting than that Leerberg's suggestion of the design space is a powerful concept. It relates to the use of generative materials as spatial organisation devices that are meant to resist Cartesian space (mentioned elsewhere in this thesis) but might be considered as a more powerful and active concept than merely spatial organisation devices. It is all about the articulation of the design environment and the spatial qualities of the design space. Sometimes it includes the structuring and articulation of simulated or speculated social, cultural, political, environmental and infrastructural forces. In the end, this design space also includes the social and material conditions of the designer as Leerberg demonstrates in his war-room-like suggestion for an immersed virtual design interface that resembles a social space for the architects. Leerberg introduces the term 'Embedded Space'. Personally I find this term a little confusing because of the buzz factor of the term 'embedded' that is already some how taken by the current fad of 'embedded technologies' in interaction design. But Leerberg successfully moves our focus to the necessity of designing the space for design and that this meta-spatial involvement will have a deep effect on what and how our design process will unfold.

Case 1: a_drift

This case is chosen because it demonstrates the development of a new modelling technique for the manipulation of surfaces.[116] Secondly it demonstrates the importance of diagrammatic thinking in such a design process and how easily it is to slip and fall back into craft-based design schemata. The case also demonstrates the problems of integrating various concerns such as material technology, into the design and it questions when and how this is best done.

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a_drift Time Capsules 1999
Finalist - Design Competition organised by The New York Times, New York, USA
OCEAN NORTH Kivi Sotamaa, Tuuli Sotamaa, Birger Sevaldson, Johan Bettum, Michael Hensel
Consultant:
Institute for Metallurgy, Technical University of Helsinki - Tero Kolhinen

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Project Description
In spring 1999, OCEAN NORTH was invited to take part in a competition arranged by the New York Times. The task was to design a time capsule for the next millennium, containing typical artefacts from our time. The capsule is to be opened in the year 3000. Our design suggestion made it to the final 10 and was exhibited at the American Museum of Natural History in New York in 1999.

OCEAN NORTH suggested an interesting concept that involved the uncertainty of the future. We suggested a large number of capsules that should be deployed in different spots on the slowly moving ice cap of the Antarctic continent. Solid objects that lay on an ice surface will be slightly warmer than the ice and hence they will slowly sink. This effect is accelerated by the snowfall that slowly builds up the ice cap. The gained height of the ice cap forces it to flow towards the coast. The time capsules should be dropped at calculated sites that will release the capsules into the ocean in approximately one thousand years. This concept involves a dynamic response to "cultural time". If our culture accelerates causing added global warming the capsules will be released much earlier. If our culture decelerates through a global catastrophe generating a nuclear winter or similar conditions, cultural time is frozen and the capsules will be released only in the very distant future.

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[116] This technique inspired the development of the generative machines in the high-rise and World Centre projects described earlier.

A second central intention in this project was to influence and disturb the selection of objects that were going to fill the capsules. These objects were collected in a public process arranged by the New York Times and the American Museum of Natural History. The selection of objects would clearly project our own self-image into the future and hence would not provide a neutral picture of who we were. Therefore we thought we wanted to disturb a process that we feared would provide an idealized view of our times. The way to do this was through the geometry of the inner voids of the capsules. By deforming them and making them narrow and tweaked we would influence the combination of objects placed in each capsule. Some of the objects might have to be exchanged with others to make them fit into the capsules. An abstract feature of the geometry would hence influence the cultural content.

To produce these awkward and resistant spaces we used generative animation techniques.

Modelling Techniques
An initial animation was generated with a skeleton animation that deformed two spheres.[117] The two spheres represented the dual chambers inside the capsules. Since the shape of the chambers was meant to influence what objects actually were placed inside, it was crucial to design them with no preconception or fixed idea of which objects were to be placed. The physical limitation of the design would influence the selection of objects forcing a certain degree of randomness in the selection and configuration or combination of the different objects. This we imagined would state a challenge to future interpretation of our times. The animations were designed to inform the coincidental design of the inner voids.

The concept was developed amongst members of OCEAN NORTH in Helsinki, London and Oslo. The initial animations were done by me. The output was sent to Helsinki were the modeling of concrete objects started. Then the digital files were sent back to Oslo. After some additional remodeling in Oslo the digital files were sent back to Helsinki were Tuuli Sotamaa created a plaster version of the objects. In Oslo the modeling continued and culminated in one final capsule design which was produced with rapid prototyping technology (Figure 99).

The use of skeletons as deforming devices to produce a source material for a final design with variations introduced a clear distinction between scaffold and template.

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[117] The initial work with the animations was done by me and the material was sent on to the other participants in Helsinki and after a period of modeling back to Oslo

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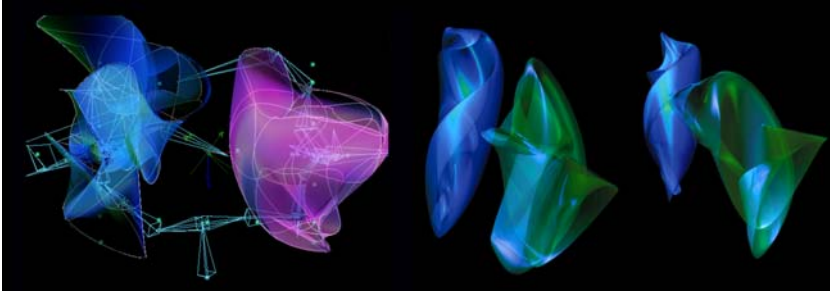
Figure 95 The skeleton with surfaces to the left and resulting voids to the right.

The animation was driven by the scaffold, an abstract skeleton creating relations between the two core chambers. The skeleton was animated manually with simple key framing techniques taking advantage of the inverse kinematics in the skeleton.[118] This movement was designed and composed on the basis of intuition as to how local movements could influence the deformation across the skeleton and with the expectation of a complex result. This results in a cycle where designerly composition in periods is resisted by generative processes. (Figure 96)
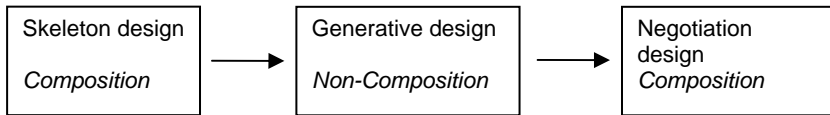

Figure 96 Generative design does resist composition but does never entirely remove it. Composition will always be a central aspect in design but we can suspend it for periods to achieve more vivid results or to let performance-driven (parametric) processes influence the result.

The chambers were initially represented through two NURBS spheres. The control vertices of the NURBS surfaces of the spheres were grouped into multiple clusters and linked to the members of the skeleton. A cluster in the AliasWavefront Studio software is a grouping of control points which allows for several control vertices to operate as one animation object. This simplifies the animation of deformation of NURBS surfaces. Multiple clustering means that one singular control vertex could be part of two or more clusters. This produces unexpected results when animated since the CV's position is

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[118] Inverse kinematics is a normal feature for skeletons in animation software that involve the definition of constraints for each hinge in the skeleton.

recalculated twice. Looping the animation will reproduce new possible configurations for each loop since the results of the last frame of the preceding loop feed into the next loop.
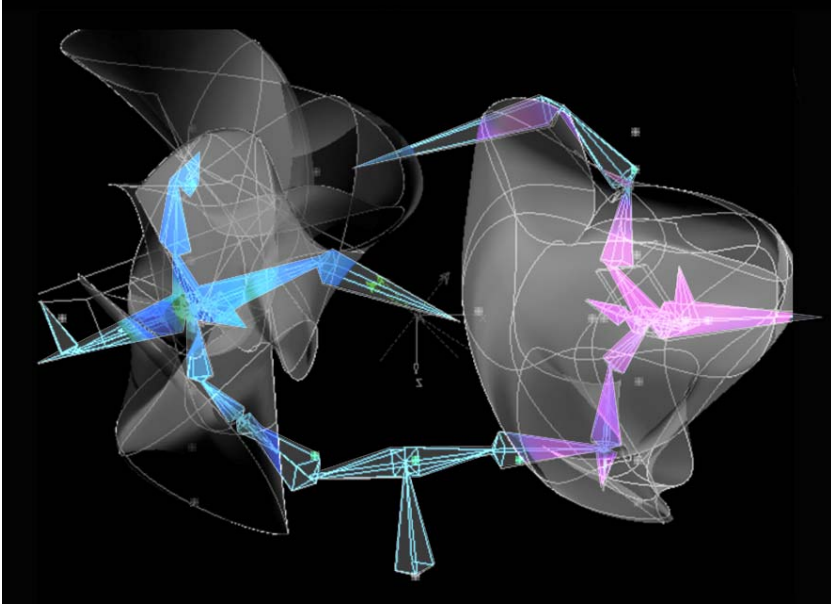
Figure 97 The skeleton branched into two branches one for each void, but also partly crossed over to the other void (middle top). Animation was done by deliberate random movements that were key-framed. Movements had a tendency to cross the field of the respective voids in a horizontal direction while the vertical movements where less clear. The movements where reprogrammed several times to achieve a result that was interesting.

The skeleton as scaffold

The skeleton in *a_drift* operates on a more abstract level than the surfaces it controls. The skeleton was never meant to be built directly or even in any way to directly influence the appearance of the final design. Its influence is indirect. In fact it is not at all possible to identify any traces of the skeleton in the final design and it stays hidden as a feature of the process. It is an abstract device for the generation and monitoring of the hidden relations between the local areas of the articulated surfaces. This scaffold was designed coincidentally with the skins it influences. Its design was developed in an empirical way from evaluating the results, first trying with only one sphere as source geometry.

This case is interesting because it implements an abstract spatial device and the production of form simultaneously. The skeleton establishes and structures a dynamic design space. This space implements the structural anatomy of the design concept, the two major active bodies and the relation between them. This relation is not only established because they share the same skeleton that branches off into two branches one for each body. But this relation is made more intricate by the interconnection of some of the branches with the opposite body. (CVs from the opposite body are multi-clustered and connected to the skeleton branch of the opposite body) This in my mind created a *Siamese Object*, both two and one engaging in a kind of abstract dance with each other or with itself (Figure 97).

The interesting thing here is that the distinction between scaffold (skeleton) and body is blurred. The scaffold reaches into the body via the CVs that can also be considered as some sort of scaffold though closely connected to the bodies. The relation is complex and involves forces of kinetic movements and the mathematics of the NURBS.

Each layer of these relations induces a generative potential, because the consequences of the system cannot be predicted. The multi-clustering contributed to this because it induced an unrepeatable element. Each loop of the animation produced new variants.

Templates and negotiation.
From the animations, a selection of frames was made and the void geometries exported to other 3D software. Several phases of negotiations were the most central design strategies when using the source material from the animations as templates for further design.

Negotiation between core and cylinder.
The capsule design is a negotiation of an 'un-designed' emergent form (template) and the outer hull first suggested as a cylinder because of production and technological constraints. The inner capsule surrounding the voids was derived from the overall shape of the voids and the cylindrical hull was negotiated between the capsule surface.
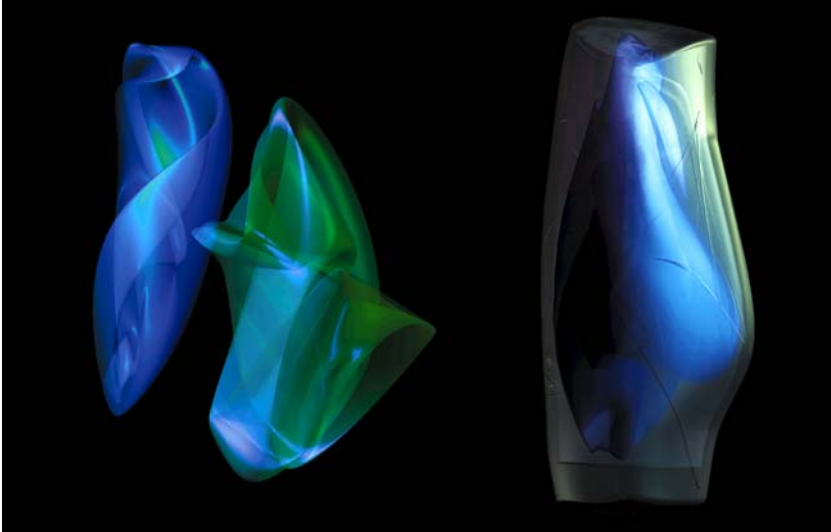
Figure 98 The resulting voids where used as templates for the design of the capsule. A seamless graduated negotiation from the inner cores (most similar to source material) to the outer hull (most distant to source material)

<u>Negotiation between secondary articulation and outer surface.</u>
In this project I experimented with a secondary level of articulation of the surfaces. In the computer model of the final design the secondary articulation was projected onto the outer surface through a technique called displacement mapping. The source image for the displacement mapping was one of the stop frames of the initial animation. The idea was to reflect the richness of the inner structures of the capsule on the outside. A still of the animation series was used as input to the displacement mapping. The surface articulation was realized in a RP-model.[119] This articulation created an additional relation between the complex geometries of the inner voids and the simpler outer shell, blurring the border between surface articulation and ornament.

<u>Resulting design</u>
One capsule was developed to a final design in several variations. The inner voids were most directly informed by the animated geometries. They where designed from the source material with only minimal modification other than

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[119] While the displacement mapping is easy to do the realisation of a derived RP-model was extreemly challenging because of the high number of polygons and the difficulties of closing the gaps in the surface edges that were a consequence of the displacement

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sorting out self-intersecting surfaces and adding surface thickness. The inner cores were suggested to be surrounded by a layer of protective ceramic material and the outer double hull was suggested to be made of titanium. The double hull contained a space for a seawater-powered energy pack and transmitter which would be activated after the release from the Antarctic ice cap.

Figure 99 Several views of the final design: To the left a partly transparent rendering showing the inner core in red. The ornamental projection can be barely seen on the surface. Second from the left: The clay model of the inner core. Notice the difference in degree of refinement or "design" between the computer model and the clay model. To the right: Rapid prototyping model of inner capsule and core voids and the outer titanium double hull with room for the energy and transmission pack in the lower part of the hull.

Redesign in another medium. Production of clay model.
In a final stage by Tuuli Sotamaa[120], the inner capsules where redesigned in clay. This process introduced a mode of traditional craft-based design, processing the 'wild' computer form into designed artefacts. Cross-sections of the final computer model of the core and voids were emailed to Helsinki as a template for the clay model. Comparing this to a similar stage in *Chamberworks* could be useful (Figure 100). The stage we compare with here is when the final computer model was translated to a producible form and construction drawings were produced.

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[120] Tuuli Sotamaa is a Helsinki based member of OCEAN NORTH.

This process was referred to as rationalisation rather than design, because it was meant to keep as much as possible of the form, only sacrificing detail when necessary because of the production requirements.

Comparing this with the redesign of the inner capsules of *a_drift* this was done on a more individual and freer level, introducing elements of personal taste and craftsmanship. This process was to a far greater degree a process of 'taming' and composition on the basis of the computer-generated material. It is interesting to appreciate the levels of development we can introduce into a generative process. Tuuli used an already developed version of the initial material adding to the level of 'cultivation'.

Figure 100 Two different redesign processes: To the left rationalising the geometries of the Chamberworks installation. All tubular elements were approximated with straight sections and circular segment sections. The intention was to lose as little as possible from the model but arrive at construction drawings to realise the installation. To the right: Tuuli Sotama's redesign of the time capsule from the a_drift project is a more personal interpretation of the computer-model where personal taste and talent are involved to create a harmonic shape.

Case 2: Tøyengate

This case will demonstrate the use of dynamic generative diagrams to articulate the design space to inform scaffolds for the design solution. The diagrams include spatial, social and environmental forces in a speculative (not simulated) manner. The diagrams are used as engines for scaffolds and eventually templates for a design suggestion. The diagrams, scaffolds and templates were negotiated towards (hmmm) the site and according to defined negotiation principles.

The scaffold is a powerful concept for the organisation and structuring of the design space. It can be operated independently from initial conditions as in the previous case (a_drift) or it can be merged from the very beginning with site conditions. An example where we explored this in depth was the *Tøyengate* project which was a distinct part of the project we called *Ambient Amplifiers* (Sevaldson and Duong, 2000a).

Ambient Amplifiers 2000
Finalist and honourable mention in the FEIDAD award.
Experimental design study involving the development of digital design techniques implemented in urban design
OCEAN NORTH: Birger Sevaldson
Project member: Phu Duong

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The set task was to intensify the use of Tøyengate which is a street that feeds into the main site of the project-, the *Tøyen Park*. The main task was to intensify the use of Tøyen Park. The adjacent streets and access routes to the park were important focuses in trying to achieve this. Tøyengate was chosen as one sample for the reinforcement of the feeding armatures around the park. It leads from a multi-ethnical township in the centre of Oslo towards the park. Along this route the intensity and density of people and activities decreases (
Figure 101). We wanted to modify this density (or decrease of density) along the route. The intensification was meant to be open ended, not dependent on particular point attractors, but articulated along the length of the street with a pulsating and varying degree of intensity and with the potential to develop and change over time. The concept implied a geometrical based approach where the main idea is that spatial richness will potentially be able to host undefined activities and spontaneous inhabitation.
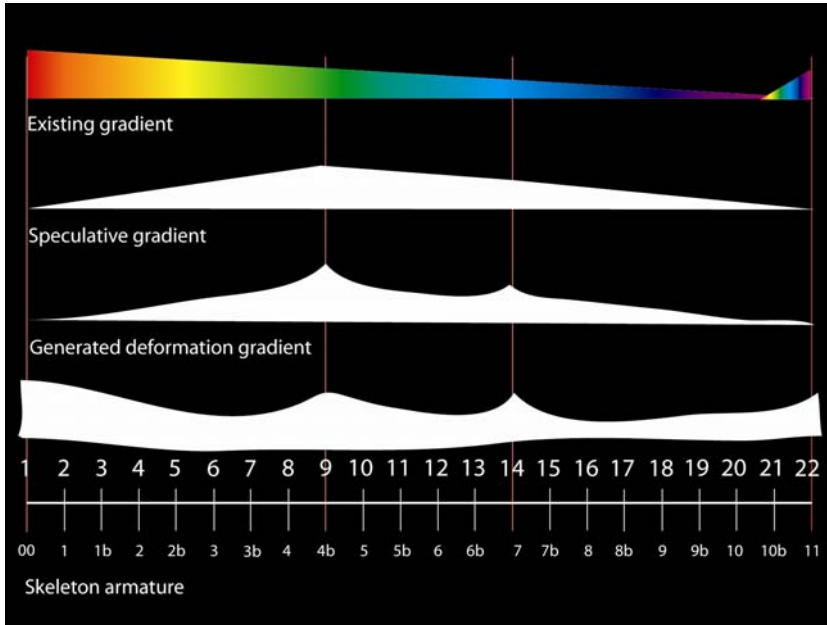
Figure 101 Four diagrams of the re-articulation of Tøyengate. The diagram at the top shows the perceived intensity in activities (density of shops, vehicles and street life) The left side indicates the end of the street that connects to Grønland and the right side connects to Tøyen park. Our task was to shift activities farther up the street (second diagram). The third diagram shows a qualitatively articulated way of achieving the shift towards a greater activity level along the street. It takes advantage of the existing street crossings as natural points for increased activity. The crossings are shown with thin vertical lines and indicated with the activity tops. The fourth diagram shows a intensity graph of the final device that was suggested for the street as an experimental concept to intensify the street, drawing on its natural internal (private) and external (public) resources.

The design process was based on a laborious analysis that was the basis of the overall interpretation of the site. This analysis included diagramming of property, social and cultural features, and geographic qualities. It included many visits to the site and vast photo documentation that fed into the concept for Tøyengate. (Figure 102) For the entire documentation see the intranet at: http://www.aho.no/staff/bs/ambient_amplifiers/ (Sevaldson and Duong, 2000b)

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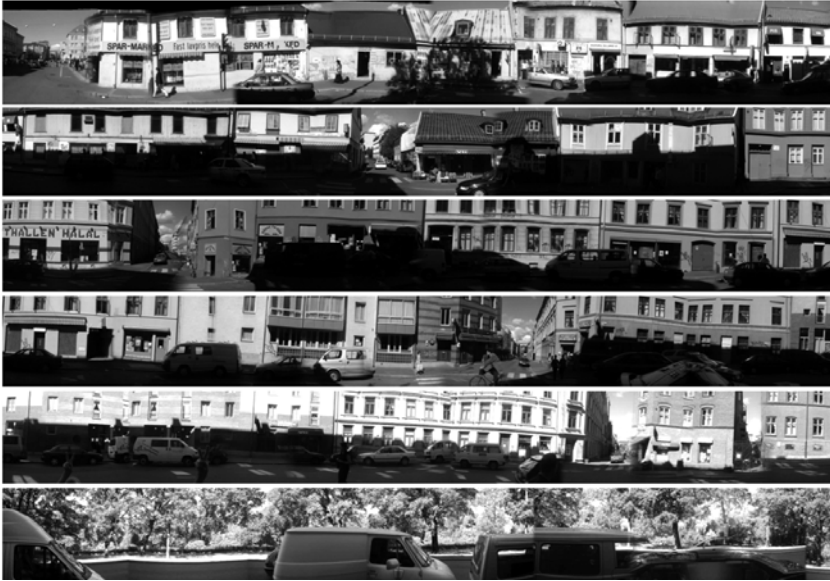
Figure 102 Composite photo technique was used to document the entire facades along Tøyengate. The image shows only a part of the length of the facades. It starts at the multi-ethnical township of Grønland in the upper left-hand corner and ends at Tøyen Park in the lower right-hand corner.

To create a design space, Phu Duong and I developed a concept of several steps and layers of generative processes feeding into each other. The process started with a particle animation that was driven by the particular features of intensification we found in our pre-study. These included 'hot-spots' of public and private activities along the street and street armatures that formed spaces that had a potential to attract activities. The most powerful hot spots we found in the street crossings. Here there was a potential for a richer street life, only triggered by the increased activity caused by the crossing of the streets. In addition, these crossings most often have corner shops that contribute to the intensification of the hot spots. These spots were implemented in the animation as attracting forces, while the particles were generated evenly along the whole street (Figure 103). The particles were used to map the form and movement of a long range of kinetic skeletons used as scaffolding devices for the design space. The skeletons were used as driving devices for several surfaces that were used as the first underlay for design. We can distinguish the different levels of design:

- Real-life source material: the existing street life, the existing geometry including the hot spots.
- Dynamic generative diagram: the particle animation informed by forces found on the site.
- The scaffold: skeletons that contribute to the initial articulation of the design space.
- Templates: the surfaces that were used as initial underlay for the design solution.

This process moves smoothly from level to level and is tentative and iterative. It is a shift of both modelling techniques from abstract spatial structure to almost concrete geometries. But it also implies a conceptual shift from abstract spatial visualization to design thinking where site conditions, materiality, tectonics and considerations about performance and adaptability slowly surface.

The process now moves towards interpretation, imagination and negotiation. Slowly we start to imagine inhabitation and concrete design solutions (Figure 108).

The negotiation phases were important and established a distance between the template and the final design. Several considerations came into play. First some negotiation principles for the relation between the street construct and the existing building structure were developed (Figure 106). Then a site-independent generic and flexible program was developed and some simple scenarios used for testing the concept (Figure 107). Finally a few real site designs were developed further and scenarios were used to validate the possible use of the construct (Figure 108).
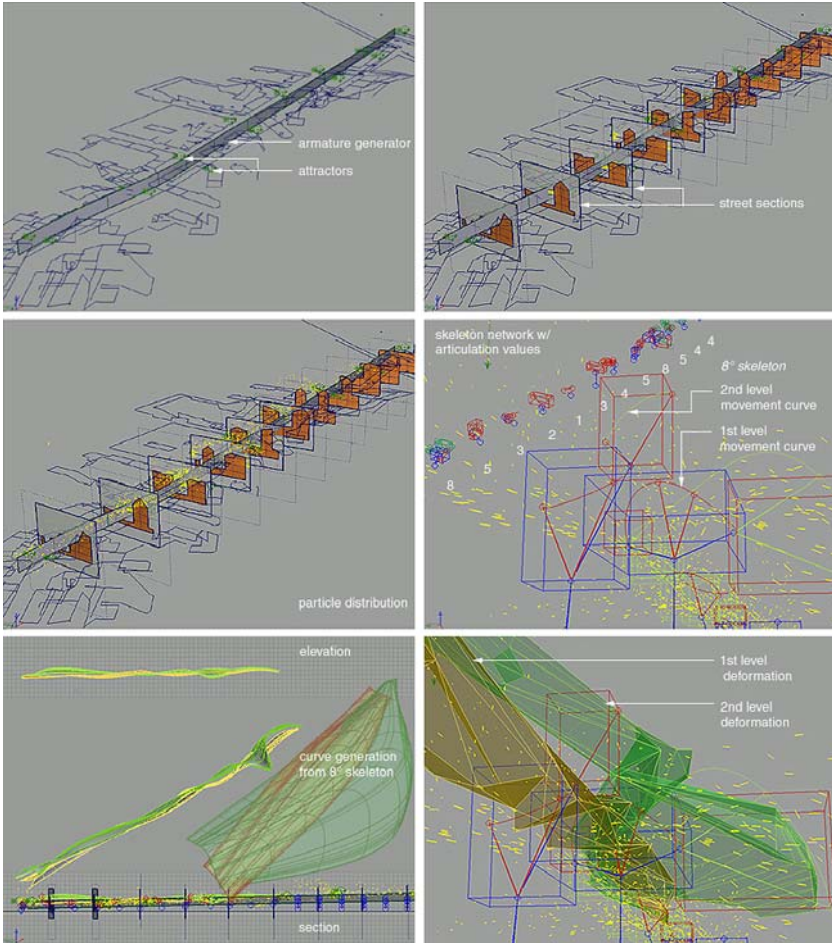
Figure 103 The development of the Design Space, generative dynamic diagram, Scaffold and templates. Top left: construction of the particle generator ('armature generator') with attractors sited at places we wanted to intensify. Top right: The existing spatial conditions were introduced as an element of the Design Space. Middle left: Running the particle animation. Middle right: Skeletons mapped onto each section. The skeletons where fed by the distribution of particles that were visible on each section in a selection of frames. Bottom left: the branches of the skeleton were connected with splines and these were used to produce the first surfaces. Bottom right: Close-up of surfaces and the two levels of deformation connected to the levels of branches of the skeletons.

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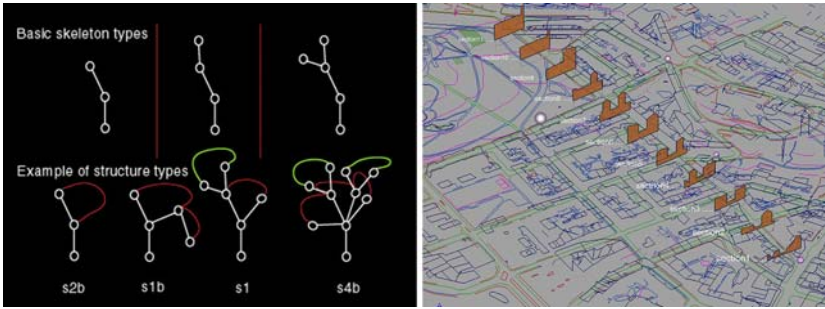
Figure 104 The skeletons and their distribution: The skeletons had one or two levels of branching and a varying complexity according to the distribution of the particles. They were allocated with one skeleton for each section.
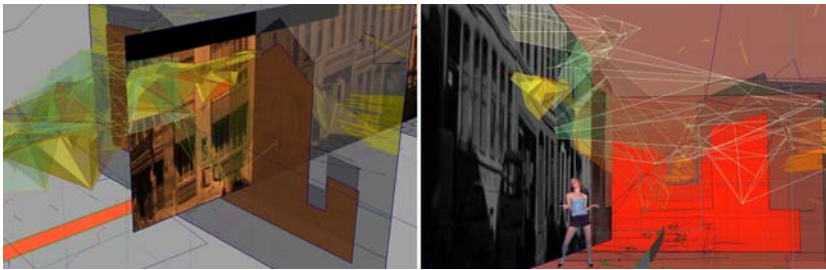

Figure 105 First design model: The surfaces have been reduced to polygonal geometries while the site data is expanded by the introduction of façade images from the site. We have reached the next phase of the design process. The next step involves interpretations of the construct and negotiation in relation to existing conditions and future possibilities and speculations about future inhabitation.
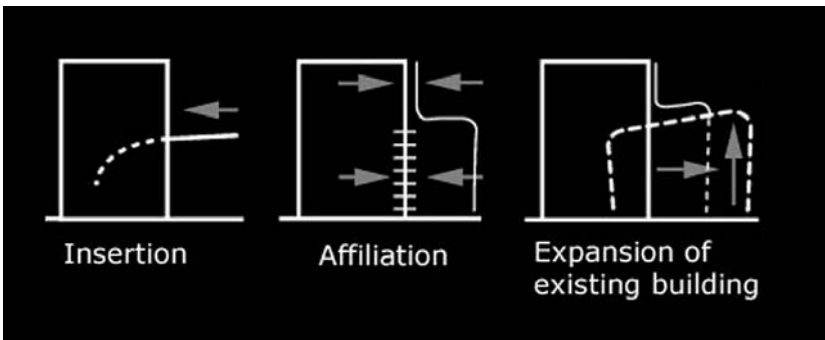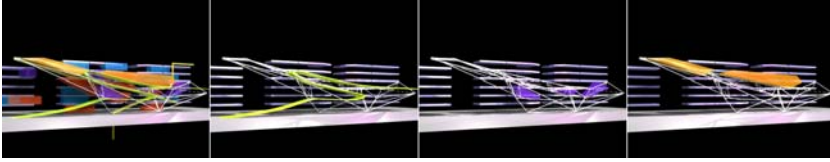

Figure 106 Negotiation principles that were intended to create closer relations between the public and the private or the street and the commercial activities.

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Figure 107 Dynamic program samples. The images show how the experimental construct could be inhabited by different private and public activities.

Figure 108 Scenarios of final result showing an exterior view to the left and an interior view to the right. Both exterior and interior are influenced and negotiated in relation to the street construction. The relation between the public and the private realm are in both cases intensified. The exterior to the left is partly occupied by private use while the balcony area of the private apartment to the right connects directly to a public pathway that floats above the street on the second floor level.

Part 4 has a descriptive character but also an element of innovation and development. Initially it poses the question *HOW?* This goes both for the description of the ways of working as well as the way this study is conducted: the question of method. The element of development comes from the fact that through description and categorization new concepts and techniques were developed and clarified.

In Part 4 I have presented our practice in a broad perspective as an overview of a rich selection of tools and techniques. I have presented an attempt at categorization so as to shift the discussion around digital design from being generic to being specific. Through real projects, I have described and discussed how things were actually done. I think this is, in itself, a novel contribution. There is little existing categorization of this field. The question HOW? is not answered with one singular answer but with a description of how things are done in specific cases. The description moves from simpler cases to more complex ones. During this movement towards greater complexity, questions of intent start to surface. These will be considered in more depth in Part 5.

During the descriptive part important concepts became apparent. Pre- and post-rationalisation strategies are developed and described. Particular care is taken in the development of the spatial concepts for the development of dynamic generative diagrams towards realisation. The treatment of the design space on several levels from generative diagram via scaffolds and templates are suggested as powerful devices to ensure a productive process between the generative source material and the final product. I think these distinctions are an important contribution to generative design.

Part 5. Ways of Thinking:
Intentions in Creative Computer Use.

We have so far investigated generative techniques in computer design from a perspective of method; how we can use the computer in a generative creative design process. Part 4 was largely descriptive. In this part, I will consider some of the intentions that motivate this way of working. As in the investigation of techniques, I maintain the frame of the thesis which is to view these issues from the perspective of practice. This means that many of the intentions which stem from philosophy and the more 'elevated' architectural discourse mentioned in Part 3 will not be presented in depth. However, certain such aspects which have particularly motivated my work will be discussed briefly and some more in depth when this is relevant to the whole of the thesis.

Once more, our discussion moves from the simpler to the more complex cases. I argue that when new design techniques are used, this is invariably part of a more complex whole in which these techniques are merged and blended with traditional ways of working. Together with contemporary intentions in design, where complex relations and negotiations are central, new techniques lead to a new design process, the hybrid process. I argue that instead of abandoning the old ways of working, the design process simply expands and absorbs new techniques and ideas resulting in a much richer and more dynamic everyday situation for the designer.

5.1. INTENTIONS

The intentions and motivation behind the various generative techniques have been discussed in general terms in part 3, New Design Techniques. These issues have also been treated in earlier published papers:
Computer-aided Design Techniques (Sevaldson, 2001a)
Published in the Nordic Journal of Architectural Research, Autumn 2001 and
The Renaissance of Visual Thinking (Sevaldson, 2001c)

In this chapter, through the presentation of several cases, I will discuss in more detail the intentions related to the techniques I have presented.

5.1.1. Categorising intentions

Categorising intentions is more challenging than categorising techniques. It is not always obvious what intentions we have. Our intentions are not always clearly formulated and they do not always correspond with what we state in public. Moreover, we always have more than one intention when we work with a complex design task. We might have intentions related to design politics, ethics, following budgets, meeting clients' requests, solving specific problems, exploring certain ideas and so on. Intentionality in the design processes is complex and layered and during a design process our intentions may shift as a result of weighting and negotiating the intentions. In this investigation only the intentions that are clearly related to explorative digital design are of interest. I attempt to map the intentions I have when I use the techniques described.

This analysis is based on personal experience and the recording of the themes that we have been working with during recent years. The difficulty in this analysis comes from the fact that the empirical material, to a large degree, is not the visual material but the thoughts I had when working with the techniques. This, together with the varied and fluid nature of the material, makes it hard to insist on consistent categorisation. I therefore prefer to use the term *intentional themes* instead of *categories*.

The analysis shows two groups of intentional themes: one that is concerned with formal, spatial and geometrical issues and one that is concerned with design questions. In both groups I found three themes (coincident). The themes are ordered from the basic to the more complex intentions.

In Peter Eisenman's table mentioned earlier the conceptual tools somehow correspond with the intentional themes I use. His list includes:

Inversion, mapping, artificial excavation, folding, grafting, tracing, marking, layering, montage, voiding, decomposition, blurring, striation, gridding, laminar flow.

I am not totally convinced by Eisenman's division into formal and conceptual tools. Tools such as blurring, tracing and inversion are, to my mind, formal tools rather than conceptual ones. Also mapping, grafting,

striation and gridding seem to span both conceptual and formal issues. In general, one can talk about concepts on many levels, formal concepts, programmatic concepts, social concepts, technological concepts or organisational concepts. The term concept is too general and we need another term.

I think that my division into techniques and intentions creates a clearer description of my investigation. It corresponds clearly with the HOW? and WHY? questions. Although I cannot avoid touching upon some issues related to intention in the technique section, the techniques are easily reworked according to alternative conceptual starting points or various intentions. The techniques are in principle neutral as far as intention is concerned and are able to 'migrate' across an landscape of intentions. In addition, a perspective involving intentions, as introduced here, is more holistic. It embraces often several techniques and uncovers the relationship between them. One intention can deploy several techniques and the techniques are not bound to specific intentions. Therefore some of the issues here will overlap with Part 2.

5.2. INTENTION THEMES
The analysis has generated the following themes:

Group one: Formal, phenomenal, spatial and geometrical issues

-**Intentions to generate exotic form:**
Used as a creative technique to break design schemata. Generative design means leaving some control to a computational process that to a certain degree produces unanticipated material. This can be a way of breaking the archetypical preconceptions of the design solutions.

-Intentions to find virtual phenomena

-**Intentions to reinvent spatial organisers:**
Systems which introduce an alternative to the Cartesian grid as spatial structuring device. These include skeletons, density maps and deformation of grid structures.

Group two: Questions of design strategies

-Intentions to produce open-ended spaces:
The design of open-ended spaces is a response to the abandoning of total control in design. The idea of control is replaced with ideas about "unfinishedness". The different social economic and cultural forces are

driving formation processes beyond the designer's control. The designer's role is to respond with flexible solutions that can be developed in the future into new unknown states. Generative design computing fits such an ideological position.

-Intentions to respond to dynamic environments through design:
A problem in design is how to respond to change. Our environments are dynamic and are constantly changing. Negotiating "wild" material opens the design for unforeseen use. (See (Hensel and Sotamaa, 2002) on the concept of vigorous environments.)

- Intentions to respond to the complexity of urban systems:
In this area we find a range of techniques and concepts that aim to deal with real-life complexity. Amongst the ideas and concepts I have been working with the following is the most central:

Generative visual diagramming produces complex geometries that, when negotiated towards real-life situations result in spaces which are adaptable, flexible and programmable, yet articulated and rich. This type of flexibility comes from the richness of these spaces. Generative diagrams and the source materials are used to implement adaptability.

In the following sections we will go through each of these themes in turn. We will discuss the themes through several cases. The truth is that in each of these cases all or many of the mentioned intentions are present in one way or another. In reality we almost always operate in modes where several concepts, techniques and processes are combined. However, in the chosen cases, the selected themes are particularly clear and any other intentions are less important. Other projects have been chosen because they are good cases for a particular theme and can be interpreted from the perspective of that theme. In the last section of this part, we will look at a case where these intentions clearly appear in hybrid combination. We arrive at the conclusion of the thesis: a clarification of a new and richer design process where the digital lives in a synergy with traditional tools, techniques and methods of the practicing designer: the Hybrid Process.

5.2.1. Cases and samples from Group one:
Formal, phenomenal, spatial and geometrical themes
Intentions to produce spatial organisers

Intentions:
The intentions in this theme are more complex than in the previous one. We are not necessarily looking for the exotic, but we want to organise our space for design in an innovative and suitable way. (Please refer to the discussion

in part 2 about generative diagrams and to the discussion on pre-rationalisation.)

Especially relevant techniques:
Intensity mapping (2D or 2,5D), density mapping (3D) Particle animations, scaffolding techniques.

Intensity mapping
This is a frequently used technique. Intensity mapping is a general diagramming technique used to map all kind of data that show variations across a space.[121] Intensity mapping as described here is a generative technique where a found or generated colour map is used as a generative diagram to inform a design space.

2D computer images are very well suited for this purpose, mainly because they are indeed intensity maps, in this case colour information mapped to an image space described with an X and Y coordinate system. The colour intensity is given by a number for each colour per pixel. The 2D image is very useful because the data is easily manipulated, translated and recoded. The computer images can be used for descriptive diagrams where the intensities and the coding very easily is changed or made totally dynamic showing development of trends. But they can also be used as generative diagrams where the colour coding is open at the beginning and coded with content at a later stage.

Intensity maps always relate to space. They render the distribution of certain issues in a given space (concrete or abstract). Therefore they are very well suited as spatial organising devices in any planning process. The intensity maps can be used to learn more about complex events like patterns of use of space or the distribution of statistic data. But they can also be used in generative design to inform the design and organisation of space, to create scenarios of future use or to act as input for scaffolding techniques.

Spatial organisation, colour space. VORB3
A central issue in the use of generative diagrams as spatial organisers is to suggest an alternative to the Cartesian organisation of space. The Cartesian space serves as a global spatial structuring system that organises the design space. It has become a universal scheme, accepted to a degree that it is taken for granted, becoming almost invisible, an organising archetype. This organising schemata needs to be challenged or sabotaged. The generative diagrams can be used as spatial structuring devices instead of or in combination with Cartesian space.

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[121] For samples of mapping of temperatures relative to geographical maps see e.g. Tufte (Tufte, 1983)

We cannot entirely escape the Cartesian space, especially in the context of computer-aided design, where both 2D and 3D software is based on Cartesian coordinate systems. But within the global Cartesian space, we can establish customised local coordinate systems that diverge from and resist the global system[122]. We can also integrate other descriptions of depth apart from the metrical, such as the visual perception of space in colour compositions. In the following example the visual depth of graphical images is mapped to various local coordinate systems.

In the VORB3 workshop of 1999 the students where asked to find a graphical image that they liked because of its structural organisation. The image should be non-figurative, it should have a certain complexity and it should render areas with varied intensity and with variation in the sharpness and quality of the borders between its graphical shapes. These images were used as source material for the generation of 3D spaces.

A colour image can be read as a data array where the numbers of each pixel can be recoded from colour intensity to z depth (displacement mapping). The initial image was filtered in Photoshop to produce a series of images, each of them operating as descriptive diagrams of the initial image, emphasising some aspects at the cost of others. For each diagrammatic image a separate rule for spatial mapping was applied. This resulted in a rich space where several surfaces intersect. Each surface indicates a local coordinate system since the z-depth is modulated into a new topologically formed position.[123]

The colour images are non-figurative and chosen only with the motivation to find a source material that is interesting. This implies a training of a sensibility towards the potential in the source material. It is a subjective forecast or anticipation of the eventual output that a generative process based on the source material would produce.

The surfaces in NURBS software have their own inherent coordinate system, positioning the surface locations according to the anatomy of the isoparms. These coordinates are normally called U and V where the surface normal corresponds to Z. These techniques are easy to conduct with the bump-mapping or displacement tools in many 3D visualisation programs.

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[122] With the terms 'sabotage' and 'resist' I whish to point to Eisenman's use of those terms mentioned earlier.

[123] Local coordinate systems are often used in CAD systems, especially for architecture. E.g. a part of the building that stands in an angle to the rest of the building could easily be constructed along its own local co-ordinate system, standing in the correct angel to the global co-ordinate system.
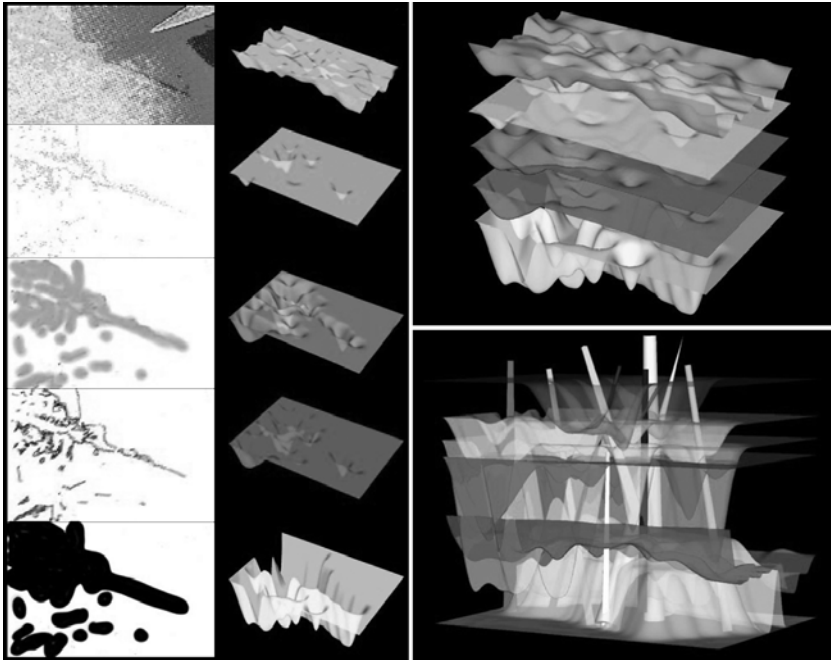
Figure 109 To the left: Intensity maps translated into spatial surfaces via displacement mapping. The top image shows the original source material to the left and the resulting displaced NURBSs surface. The following images show different filtering results and the corresponding displacement maps.
 To the right: Spatial construct derived through displacement mapping. Additional diagrammatic elements depict relations between high intensity areas in the different layers. (Students: Fredrik Jean Hansen, Bendik Skilbrei, Rolf Gregersen 1998)

The next task was to use the generated spatial diagram as a starting point for the design of a physical model. The development of the physical model was not meant to be an exact rebuild but the spatiality should be developed further according to the restraints and possibilities provided by the new material.

This resulted in several different approaches which all were interesting because they challenged the use of materials. Some of the models involved dynamic materials like water animated with airstreams and smoke chambers. In this case the students used different coloured jelly from the super-market as the building material for their model. They used the digital space as a drawing for the jelly space, calculating that the difficulties of controlling the material would introduce new and unforeseen features into the space. The building material for the model became a generative tool.
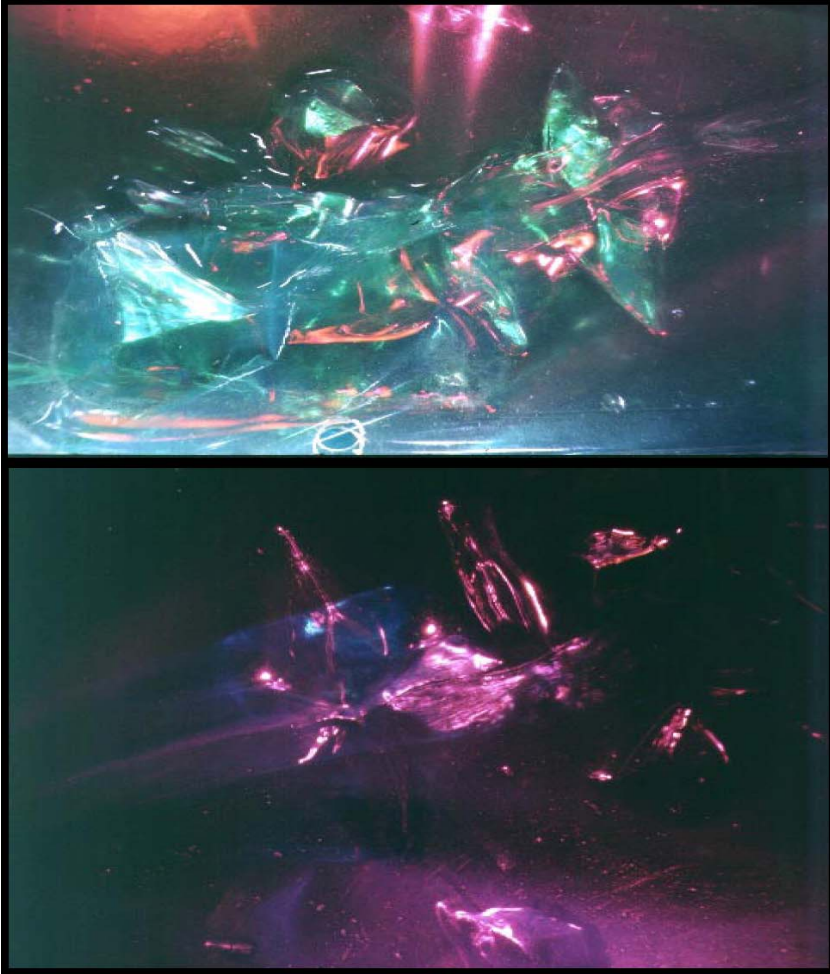
Figure 110 The diagrammatic space produced in the 3D software was used as an underlay in an experiment where a similar space was constructed as a physical model. Interpretation of spatial effects was central. The images show a spatial model constructed from gelatine. The realisation resulted in a space that was quite distant from the "drawings" because of the material restraints and potentials that developed the space in a new direction. (Students: Fredrik Jean Hansen, Bendik Skilbrei, Rolf Gregersen 1998)

In the next example the depth information was simplified and represented as columns (data reduction). Instead of a normal X, Y, Z system, a cylindrical polar co-ordinate system was used to map the space.[124] The polar system is

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[124] Kristina Ruf

described by sweep angle, radius and height. The x and y coordinates were mapped to angle and height while colour intensity informed the radius values.

Combining several similar approaches would produce nested local coordinate systems for a richer spatial structuring. Though these approaches still operate within the Cartesian global system they help to resist the Cartesian paradigm.

In this case the physical model was built in Perspex in a water tank were the water was animated with several air streams creating a suggestion of a dynamic element in the model. Compared with the first model, this one was very precise but differed from the digital model that was developed in parallel.
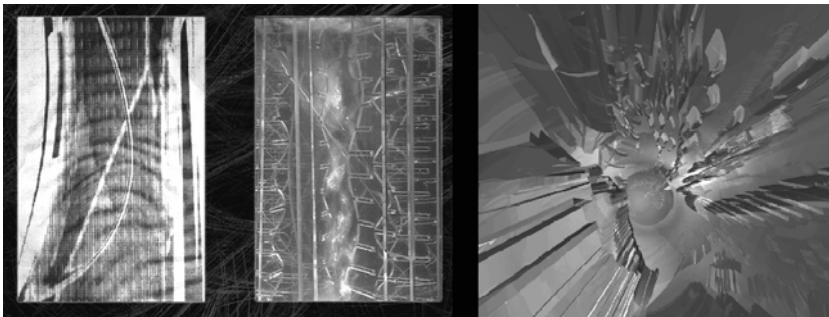
Figure 111 VORB3: To the left: Initial image sample. In the middle: Physical model of polar (cylindrical) space. To the right: Digital model of polar space, looking down the centre axes. (Students: Christine Ruf, Helje Beisland, Ståle Møller, Jan Chrisitan Rasmussen.)

Density mapping

A recurrent question in the representation of space with computer technology is how to represent space with means other than surfaces. The focus on the surface in general (architectural discourse) and spline surfaces in particular (in CAD) has moved attention to other possible ways of representation, ways that might have greater potential for representing complex special organisation.

The implementation of a spatial representation that is not based on discrete objects (surfaces), but which instead treats space as a continuous articulation of a volume with varied densities, colouring, opacities, velocities and directions would have a remarkable impact on our conception of space and how we design in that space. These issues have only been investigated

sparsely. A study published by Thomas Fischer and Torben Fischer does not actually raise this question though their development of spatial representation software and interfaces and teaching approaches to the issue are very successful (T Fischer, 2003).

A Voxel-based system is the only principle that fully describes a 3D space in a computer. Scientific simulation and visualisation is dependent on the continuous representation of three and four-dimensional space. The use of surface geometries to represent fluid dynamics is not sufficient.

Scientific visualisation technology is based on Voxels. Voxels are spatial equivalents to pixels. Space is divided into cubes representing the smallest spatial element. Each element can be assigned with values like density opacity, colour or directional vectors. Spatial variations are described continuously across the volume. In our investigation we researched scientific voxel software. But we also investigated other spatial representation techniques that are derived from other geometries than surfaces. Particle animations have been a useful though incomplete alternative to Voxel representation.

Experiments with Voxel software.
In 1993 I contacted the researcher professor Øyvind Andreassen who introduced me to scientific visualisation software based on voxel technology. The software called *VIZ* was developed by his colleagues at the Norwegian Defence Research Establishment. With the help of Øyvind Andreassen I started to experiment with the software and investigate its potential as a design tool for spatial design. We soon realised that we could use the software in a generative way in initial design phases and export geometries to the traditional CAD software for further development. The exportable geometries were poly-surfaces generated from the voxel data.

After the initial design phase in the voxel software, we wanted to move on using the generated material as a scaffold or template for design. This meant exporting data from the voxel software to normal CAD software. This was only possible in the form of surface geometries. Iso surfaces were derived along voxels with the same density. The richness of the voxel space compared to the surface representation became clear when we found we could derive hundreds of surfaces from one voxel space. Our experiments stopped because of software and hardware problems and lack of programming skills. The voxel software has no interface and the question remains how to produce architectural spaces with the software. The few programming attempts I made contain errors because of difficulties with compilation on the various platforms involved, but still they do give an indication of the potential.

Voxel software has been around for many years and it is really an old principle. But the voxel has still not found its way into the field of architecture and design. Here surface-based packages dominate. The problems of programming and generating voxel spaces and the difficulties of how to develop the geometries from voxel software has partly been a cause for the absence of voxels in the realm of architecture and design.

A commercially available alternative to voxels is particle animation systems. It is important to keep in mind that these do not match the potential in voxel representation of space. Whereas the voxel system represents space continuously, particle systems only articulate space fractionally. Densities in space are represented by densities of entities (particles). This creates a space that is not continuously described but where we need to interpolate the spatial data.

A case: Chamberworks

In the installation Chamberworks (Gallery RAM, Oslo, 1998) we developed an alternative method of spatial representation. The project developed through various stages. However, in none of the stages were surfaces used as spatial representation except to indicate the existing gallery space.

Chamberworks
Installaton at Gallery RAM Oslo 1998
OCEAN NORTH
Johan Bettum, Kim Baumann Larsen, Birger Sevaldson, Kivi Sotamaa, Markus Holmstén, Michael Hensel
Project Member: Dan Sevaldson
Sound: Strype Audio - Audun Strype
Video: Øyvind Andreassen FFI

Project description:
The Gallery Space of the Gallery RAM is a singular rectangular space. This space was painted all white. Taking this space as a given starting point we intended to give it a detailed articulation. This articulation of the space should be abstract and resist any typology yet it should provide for a rich spatial experience and the possibility for diverse exploration of the space. We achieved this by using bent steel tubes and rods which moved through the space in a seemingly chaotic manner. In truth they were carefully designed through several stages of digital and physical modelling informed by a digital source material. The result was an ambiguous space which was very simple, containing only the tubes and rods, but at the same time immensely complex. The space was enhanced with a soundtrack and a simple motion-triggered lighting system.

The space became very emotionally stimulating despite its abstractness. One of the highlights was when an elderly architect who had started his career in the 1920s entered the space and commented: 'Never have I seen such a richness created with so little means.' We eventually labelled this 'style' *complex minimalism*.

The project description from the OCEAN NORTH website is here slightly modified:

> Chamberworks was a temporary installation in a gallery in Oslo in June 98. The installation consisted of welded steel rods and tubes painted white; a motion-triggered, interactive light-scheme; a sound-scape using 4 loud-speakers, one positioned in each corner of the room; and a video showing advanced 3D modeling of vortex phenomena. The continuous curved and linear steel elements were pre-formed and welded together in the gallery. The floor and walls of the gallery were painted white.

> The aim of the project was to create a space with complex and changing interaction between the visitor, the spatial frame of the gallery and the material, structural, and ambient constitutive systems in the installation. The project provided a space for the unfolding of a simple, dynamic relationship between visitor, spatial frame of the gallery and systems of the installation. The available space for the visitors' movement was articulated as a knotted loop allowing for various routes through the installation. The ambient conditions produced by the motion-triggered light and sound systems resulted in changing virtual spaces characterized by varied intensities and distributions of light and sound relative to the visitors' movement. A visitor's choice of route through the installation was partly influenced by these ambient effects triggered by the co-presence of other visitors in the gallery.

> The choreography of the linear and curved physical elements produced perceivable inter-relations between sub-spaces in the gallery that changed from affiliate to non-congruent according to exact geometrical boundary conditions drawn by the tubes and rods. The linear and curved elements engender a transparent space of emergent forms. (OCEAN-NORTH, 1998)
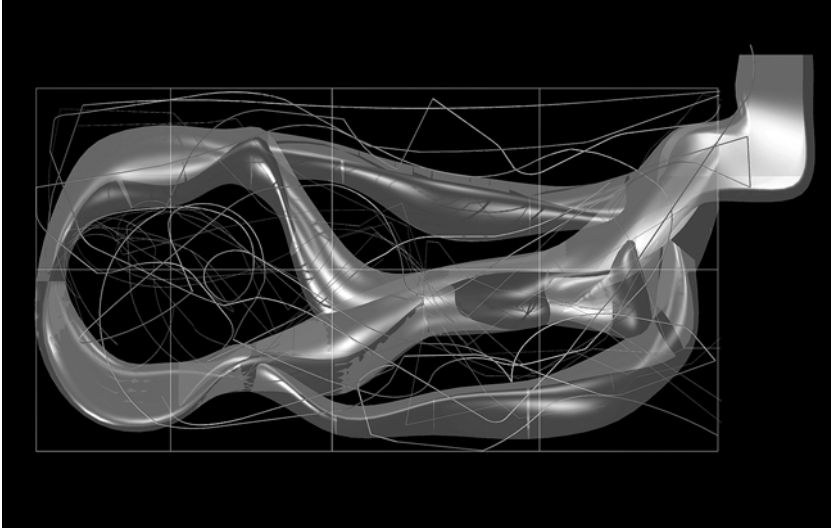
Figure 112 Top view of the gallery space (thin straight lines), installation (thin curved white lines depicting the tubular elements), with a superimposed diagram (the warped surface volume) showing the volume of the potential space for unhindered movement (Kim B. Larsen).

In the following analysis, we are mostly concerned with the design process for the installation, which demonstrates the use of particle systems to inform the density of the space. The example is relevant since the intention in Chamberworks was to produce a complex spatial articulation that did reach beyond the limitations of the surface geometries. The process involves extensive translation between digital and physical representations. The initial source material was a particle animation (by Kim Baumann Larsen) which was used as a density mapping device for the gallery space (see Figure 113). A stop-frame with relatively big variations was chosen as a guide for the density distribution in the gallery. Simultaneously, a concept for the physical realisation of the spatial concept was developed. This concept was realised with a tubular structure, resembling a vector space. It was suited to generate density variations and introduce directionality. The initial concept sketch, a scale model with loosely indicated tubular structures in the form of wires was fused with the density model. To achieve this, a physical model with a primitive measuring device was constructed (Figure 114). Photos of the wire model where projected onto three planes, floor plan and two sides. The density particle model was sectioned; the sections where printed on overhead transparency film and mounted in the physical model at the corresponding places. The measuring device was used to negotiate the two source models in the redesign phase and a new and more detailed wire model was built. This model was digitised with a *Microscribe* digitiser.
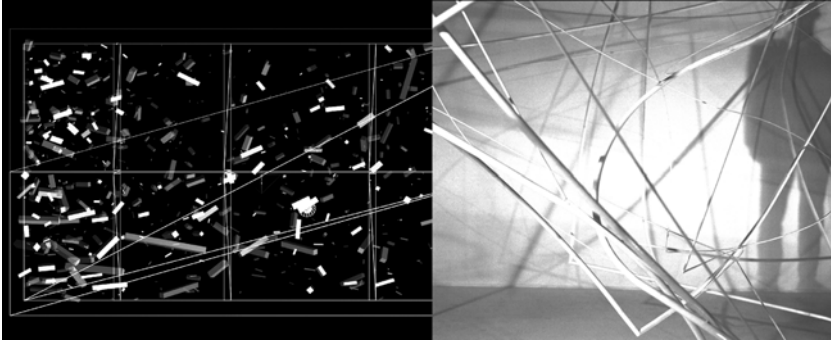
Figure 113 To the left, the initial particle animation, a dynamic spatial density map, that was used to initiate the process and as information for the modification of the structural concept. To the right: the final installation. (Particle animation by Kim B. Larsen, Photo by Ole Musken)
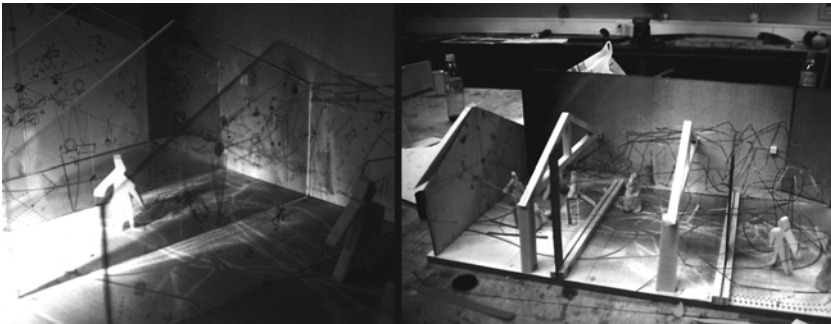

Figure 114 The digital model was rationalised by approximation of the NURBS geometries to fit with straight lines and circle segments. This allowed the production of simple construction drawings which were taken to a metal workshop for prefabrication of the elements. The result was rather imprecise and the elements where negotiated on site. This meant that the design process stretched into the construction of the installation. The modifications did not only involve "correction" of imprecise geometries but also on-site consideration of the installation.

The final installation produces a space derived from the initial density mapping but which has travelled a far way along a diverse process and through many translations. This process negotiated between spatial constrains, the conditions from the chosen construction concept, the introduction of human scale and the design of possible paths where people can move around the installation.

Figure 115 The digital model was rationalised by approximation of the NURBS geometries to fit with straight lines and circle segments. This allowed the production of simple construction drawings which where taken to a metal workshop for prefabrication of the elements. The result was rather imprecise and the elements where negotiated on site. This implied that the design process stretched into the construction of the installation. The modifications did not only imply "corrections" of imprecise geometries but on site consideration of the installation.

Another important and ever present negotiation factor was the design intention that consequently resisted typology. When ever a space became too "cave-like" or some elements formed a clear spatial division that could have the features of a "wall" we altered the elements to move it away from such associations. This modification was done in the final installation, and involved mostly the secondary tubular system, the thin rods, which were less accurately defined in the CAD-model and not prefabricated as the thicker primary tubular system. The result was a 'floating' partly un-designed and ambiguous space that at the same time was particularly articulated and partly was designed to the smallest detail. It is a good example of how the un-designed and emergent can merge with the planned and designed.
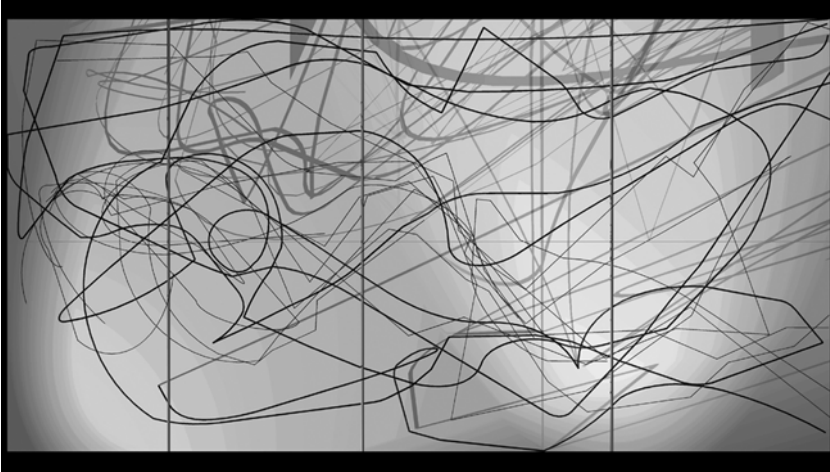
Figure 116 Top view of the digitised model. The final physical wire model was digitalised with a Microscribe measuring device. The software used was Rhino3D and it was set to draw NURBS directly from the measuring points. This led to a simplification and refinement of the geometries within the measuring process. In this rendering it is already apparent how the shadows play an important role in the blurring between gallery space and installations.

<u>Intentions to produce open-ended spaces.</u>

<u>Intentions</u>

Open-endedness is a strategic choice to prepare for negotiation of unforeseen futures. This is an issue in many of the given examples but in this chapter I will look at this topic especially.

<u>Relevant Techniques</u>

Animation based techniques, grafting, data reduction, data expansion, sampling.

<u>The source material</u>

Synthetic Landscape[125] was a conceptual research project, partly financed by the Norwegian Research Council. Intermediate stages have been presented at exhibitions at the Hennie Onstad Centre for Modern Art, Norway (Phase Two) and at the Architectural Association School of Architecture in London (Phase One and Three).

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[125] Synthetic Landscape was initiated by Johan Bettum, former member of OCEAN Oslo, who also developed the initial concepts and theories of the project. We worked closely together during most of the stages of the project. My contribution was on the development of computer based design techniques.

From the long-term work with Synthetic Landscape several concepts have been developed. In this thesis only one of the concepts and a narrow segment of that concept will be presented.

The prototype

The prototype in this case is produced as a dynamic generative diagram for the generation of spatial structures in Synthetic Landscape Stage 2. The Initial phases of the project have been described and discussed earlier in section *3.10.2. Generative diagrams.* We will in this part describe how the source material generated from the colour graft was used to explore the possibilities and potentials in the development of space. We will return to the later stages of this long-term project in section 5.2.2. . Here we will discuss the initial phases of the project and how it was used to initiate new design processes for emergent spaces in several workshops.

To investigate the spatial potential of the graphical information, the initial colour graft was processed in several stages. The different colour channels were isolated and used to map colour intensity to 3D surfaces. The separated surfaces were juxtaposed and intersection lines were generated to extrude the minimum common data. Time cursors were applied to the intersection lines and animated along these lines to add a time dimension. Finally a selection of the cursors was equipped with forces and particle generators, to render possible interaction fields between the cursors over time. This is one line in a process that branched off in several directions (Figure 117).

This process is a cyclic exercise, letting the data set split and blend, grow, expand and shrink, producing continuously new representations that are nevertheless related. This shrinking and expanding of the data may be regarded as an inherent part of data translation. The consequence of interpretation involves a form of a reduction because the material is understood in a certain way at the cost of other possible readings. The shrinking of the data to a degree comes as a natural consequence of specific interpretation of the data and the following reconstruction based on that interpretation. If this reconstruction involves successive stages of generative computing or graphic transformation, the data tends to expand again and a new interpretation will follow. During or via these steps the graphic material is increasingly understood as definite objects, architectural space or urbanistic items and conditions.

Extraction of representative minimum data like the production of intersection lines reduces the data fields to a level of complexity that is comprehensible. If we add generative techniques (like in this case the animated cursors and particle generators) the information fields grow in complexity and new configurations appear. Repeated reductions of the data sets are important in the process of re-utilising them or codifying them at a later stage.
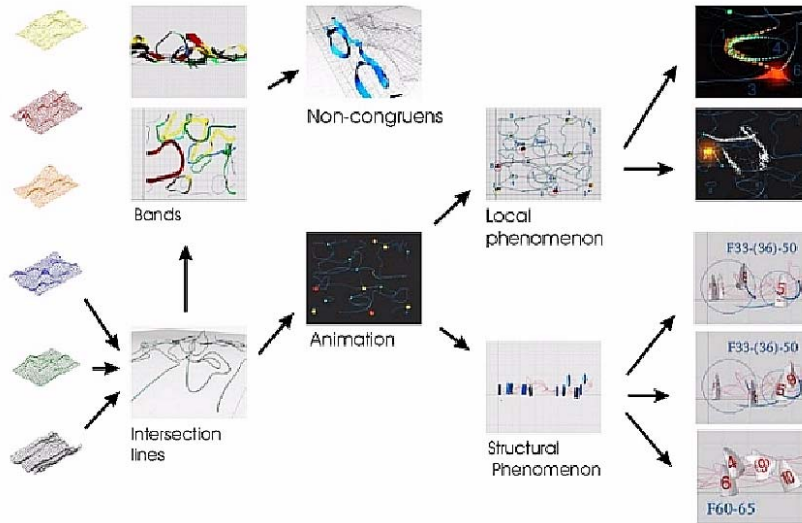
Figure 117 The process spanning over several "generations" branches off into lines that are investigated separately. From the left: Displacement surfaces informed by the different channels from the colour graft, Next column: intersection lines generated from juxtaposing the surfaces. Next column top: ribbons between two non-congruent lines derived from the intersection lines. Below: Spatial cursors that were animated along the intersection lines. Top right: investigation of local spatial and time-based phenomena including spaces produced by particle animations where the cursors are used as generators and forces. Below: Investigation of structural relations over time between the cursors seen from the front.

The result of this process was several animation sequences, some investigating specific phenomena, others producing complex dynamic particle fields for use as dynamic generative diagrams. The particle animations were chosen as a starting point for further research. The task was to investigate how we could use this material further in a design process. The final goal was to reach a stage where we developed new spatial concepts and finally where a process of translation and interpretation would lead to buildings, landscapes and other artefacts. We used a teaching commission as an opportunity to investigate these issues.

The test ground
To test the prototype according to the research design mentioned, one needs a wider context. Student classes and workshops are well suited for this purpose. The ideas and concepts generated in Synthetic Landscape have been tested on several occasions, including the subsequent VORB workshops and the "Dynamic Relations in Design" workshop series conducted in co-operation with AA (London). Another occasion was a parallel workshop at

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the University of Art and Design in Helsinki and at the Vaasa Institute of Technology in 1998, called "Building Dynamic Relations"[126]. Aspects from this workshop will be discussed further here.

The students were third and fourth year architecture and interior architecture students. Our design brief implied the interweaving of diverse systems involving relations and interactions between entities and forces that were found in the source material. We developed a speculative strategy to build adaptability into a system. We intended to design systems that were able to adapt to unforeseen future contact with other complex systems. This type of adaptability is achieved by imposing a minimum of one system onto another and to negotiate and relate them to each other. The idea was that in this way we would manage to built adaptability specifically into the systems and that they therefore would have the potential to adapt to future system changes or exposure to additional systems. The process required the students to select, analyse, and interpret certain parts of a given source material. Then they had to build a physical model of at least two different materials representing different interacting forces or systems found in the source material. We emphasised that this was meant to be an intermediate step towards architecture and not yet a model of a building design. The relation and interaction between the systems should be developed through the physical model. Additional scenarios of usage should be developed, preferably also informed and mediated by the source material. Finally a design for a small building should be derived.

We wanted to make the students depart as much as possible from their usual way of working. This could only be achieved by guiding them into lengthy processes through which they became used to attempting translation processes that involved serious consideration of both global features of the material and also the details. It also involved interpreting the source material in more than one way and for more than one purpose; as formal input, structural diagram, relational principles or diagrams for speculations about usage. The intention of encouraging the students to depart from their usual way of working was constantly challenged. Frequently the students relied on their preconceptions when they ran into difficulties, as demonstrated in one of the shown cases (Figure 126). This happened with all projects but at different stages. Therefore I cannot show one continuous successful case but will show the several stages demonstrated from successful samples from different groups.

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[126] This workshop was an OCEAN workshop run in parallel in Vaasa and Helsinki involving Michael Hensel, Kivi Sotamaa, Markus Holmstén, Kim B. Larsen, Johan Bettum and my self as tutors.

The source material was the particle field animation from the Synthetic Landscape project. In addition to the video, still images of the top- right and front view for each tenth frame were given (

Figure 118). This selection was necessary because of the huge amount of information a complete printout of every frame would represent (data reduction). The material was delivered both in digital form (2D-images) and as prints. This meant that the 3D time-space was only accessible through 2D "time-sections" and 2D video animation.

Frame 110   Frame 140   Frame 170
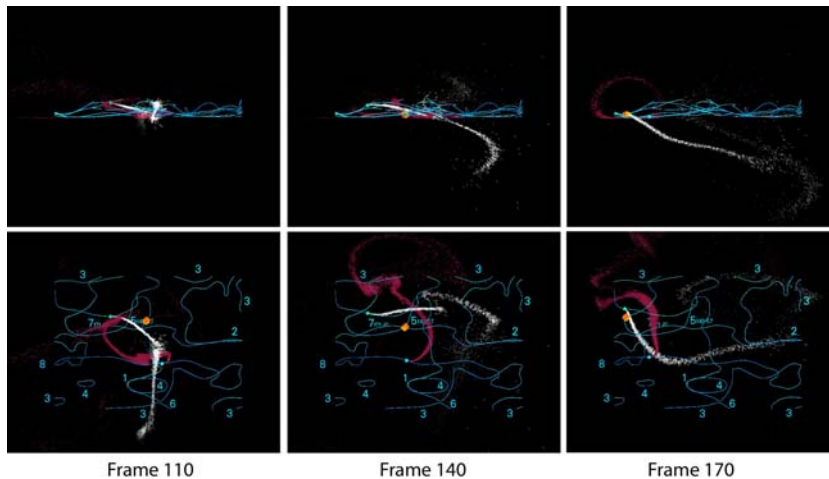
Figure 118 Source material, single frames presented together with the animation video. Top row: side view from the right. Lower row: top view. With this information the students were able to derive spatial information from the material.

The students were encouraged to develop a number of ways to analyse the animation. The first step was an analysis on a generic level to derive spatial and organisational principles. Brainstorming techniques were used to generate concepts to comprehend significant time / space events (Virtual Phenomena). Some of the students used graphical filtering techniques to clarify and diagram the images of the source material (Figure 119). The generative diagrams were derived from the source material through various steps of transformation. Transformation processes were driven both by manual drawing, physical modelling and by digital manipulation. Manual drawing was in most cases closely integrated with analytical interpretation, while digital recoding turned out to involve less interpretation but more of post rationalisation and subsequent interpretation. Individual interpretation, redefinition and redesign through selection are important elements in the transformation process.
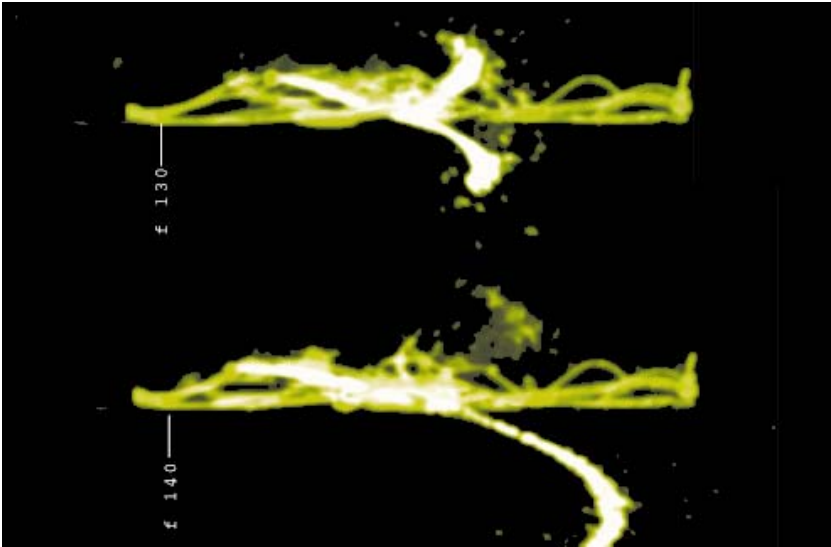
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Figure 119 A side view of the particle animation was used as source material for developing an analysis that resulted in some spatial typologies. In this case the clear division of the innermost very light zones resulted in a concept the students described as 'energy fields'. (Helsinki workshops Group 3)
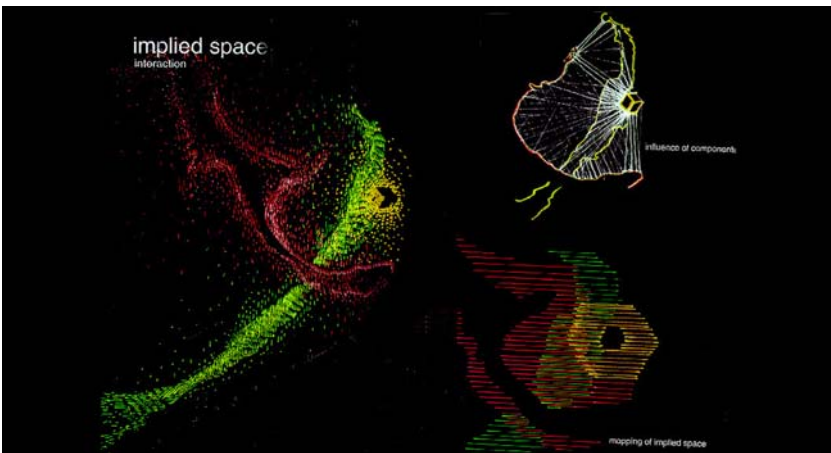

Figure 120 Different readings of one frame from the source material. To the left: A redrawing of the source material with emphasis on distinguishing the various elements and clarifying densities. Top right: An interpretation of the mutual influences and relations between the main formations. Lover right: An interpretation of the "implied space" generated from the density analysis and the influence analysis.
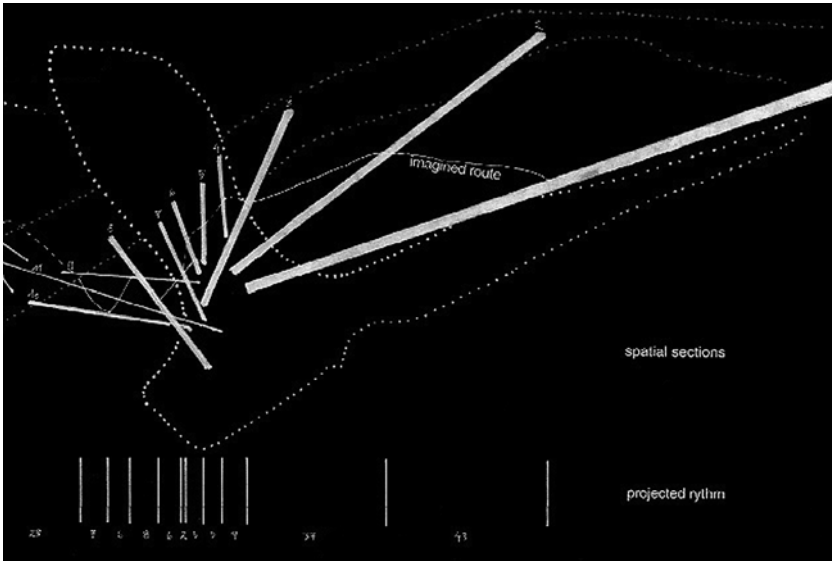
Figure 121 A resulting interpretation of a possible overall structure of the space derived from the analyses above and additional analyses. The lower part of the image shows an analysis of the spatial rhythm in the space.

The manual drawing analysis investigated the source material for structural features like densities, directions and relations (Figure 120). Also more overall features like the rhythms implied in the space were investigated and described with diagrams (Figure 121).

Each group had to select some of the found and developed analyses and material for development into a physical model. The criteria for this selection were the potential of the phenomena to be developed into generative diagrams. Some phenomena were analysed as principal force- direction- and-density diagrams. Others were used as colour underlays (colour grafts).

In the example in Figure 119, the students interpreted the graphic material as two separate degrees of intensities which were formed into two material systems that were interacting. They used physical model building to construct a diagrammatic model of the resulting space (Figure 122). The two different systems were constructed in two materials, wooden sticks and Perspex plates. In the resulting model, the two systems are closely related and intertwined, and the choice of the two materials also contributes to the closeness between the two systems. Though the two systems are clearly distinguishable under close inspection they blend when looking at the whole. This produces a smooth relation between the two systems. The sticks of the wooden system are mirrored in the edges of the plates, while the plates of the

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Perspex system are mirrored in the facets of the sticks. They are similar in form on a formal level which creates this close relation. Such a model is a brilliant tool to investigate relational principles between two distinguishable material and programmatic systems. The model was used as a basis for a further development into a small building where several systems were put into play and related to each other (Figure 123).

Figure 124 shows a similar model where the interrelation between three systems was investigated. This model is much more diversified. It is also a model built of wood and Perspex but the treatment of the materials is totally different. The Perspex is not applied spatially but creates a kind of two-dimensional plane constituted by a transparent and opaque plate, with a superimposed spatial wooden system. Also the formal treatment of the information in the three systems is diverse adding to the disintegration of the model. The Perspex systems are edged while the wooden system is smooth. Despite this departure from the investigation of smooth and close relations between several systems, the model is interesting because it still manages to connect the three systems on an overall level.
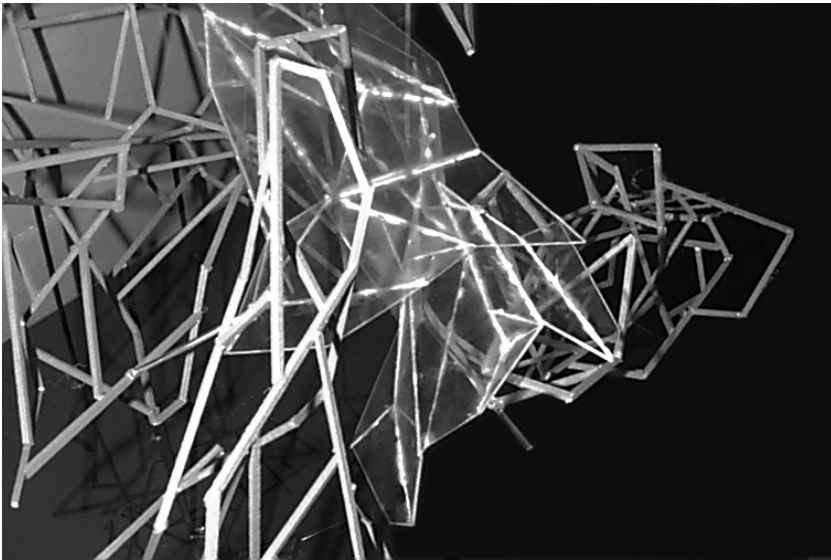
Figure 122 The division between the force fields and the lesser energetic zones was developed into this model with two interrelated systems in two materials. (Helsinki workshops Group 3)
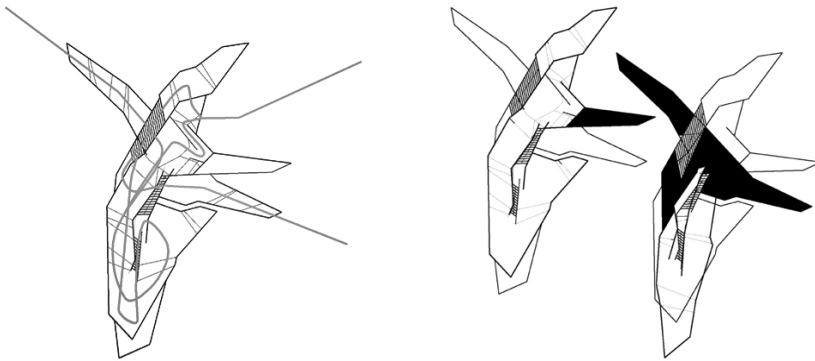
Figure 123 From the above model the students developed a small building that took into consideration the co-existence of two or more systems including the design of a fluid circulation pattern layout. (Helsinki workshops Group 3)
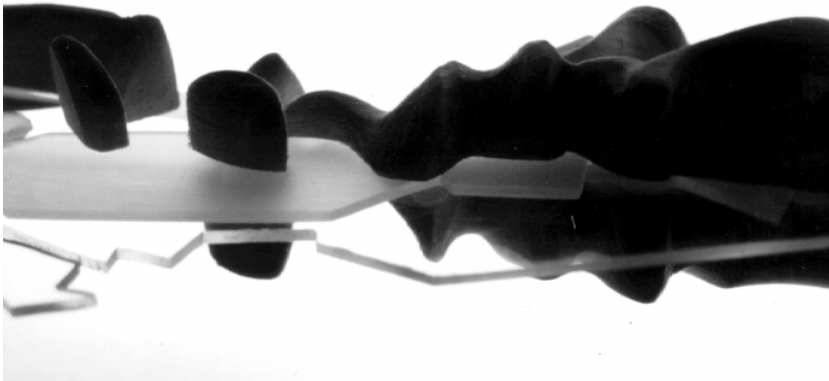
Figure 124 A similar model to the previous one consisting of three interrelated systems. But this model is produced in a different way with other materials that produces a very different space. The choice of modeling technique leads to different spatial readings. (Vaasa Workshops)

The two models demonstrate two different approaches to the treatment of relations between systems. The development of the first model involves investigating the details of the interaction between two systems and developing a sensibility towards nuances and small variations. Further

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development of the second model would lead to the development of separate bridging devices between diverse systems sharing the same space.

The third sample shown is again diverse from the others (Figure 125). There are three systems and materials involved: a system constructed with wooden sticks, a system constructed with a steel mesh and a system constructed with Perspex plates. All three maintain autonomy and there is not much interaction between the systems other than that they share the same space.

The students used the model building in almost in the same way as they would sketch by hand. Still they manage to create some kind of relation between the elements. But this relation is a totally different one than in the samples above. While the samples above investigated spatial relations between systems, this sample creates a relation through composition. The elements are put together in way that balances the whole (Figure 126).
The result is beautiful, but does not really develop any system relations and interplay between different systems as found in the source material. It is an approach to generative material, where free inspiration and association is involved. This might be an approach with less potential to exploit the inclusive design strategies following computational design.
This sample is shown to clarify the distinction between the different possible approaches. The previous samples clearly have a greater potential for development along inclusive design processes that lead to a design that involves, for example, performance and adaptability.
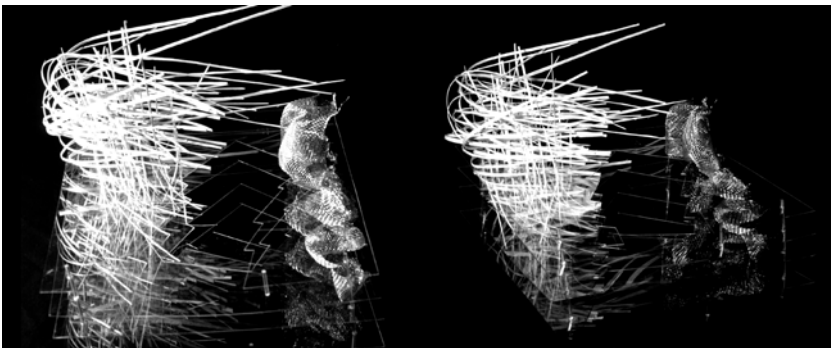
Figure 125 Some of the students had a free interpretation of the source material. This model shows the interpretation of three systems that share the same space but which do not develop the organisational relations between the systems. (Group 4 Helsinki)
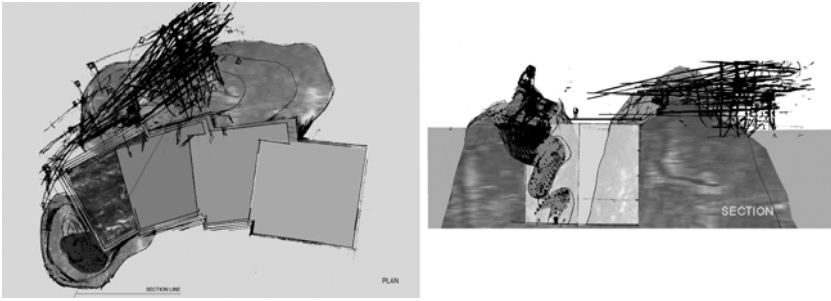
Figure 126 The group's final design solution shows clear similarity to the previous diagrammatic model. There is almost no transformation from physical model to final design. The main element in the design is an organization of the systems according to composition. The result is a fairly fixed configuration of three systems and the requested adaptability is not apparent in the result. (Group 4 Helsinki)
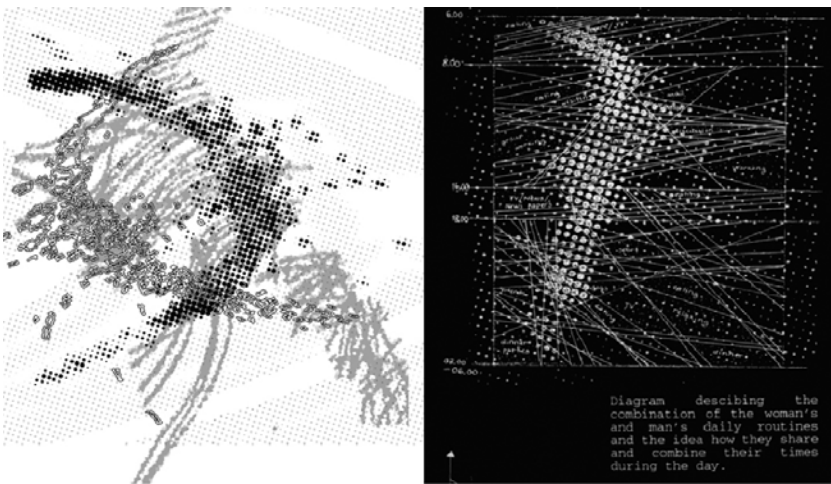

Figure 127 The students created detailed user profiles and diagrams of usage over time as an underlay for the design of a dwelling. In this case material derived from the particle animations was used in a diagrammatic matrix to induce an element of uncontrolled and unforeseen behaviour in the user scenario. To the left: the processed manual diagrams derived from the source material. To the right: a diagram of the user's day was populated with the generative diagram creating the timing of activities. The diagram shows a vertical timeline on the left while the level of activity is mapped along the horizontal axis. Though the diagram is unclear, it demonstrates a clever way of using generative source material to inform actions rather than space. (Vaasa workshops)

A demonstration of this potential is the use of the source material to inform actions rather than space. One such example is shown in Figure 127. In this case, the students invented a user profile for a pavilion placed on a chosen site. Based on the user profiles, the students developed detailed user scenarios using generative techniques which involved diagramming. The source material was here used for generative diagramming of the user scenarios to create "unplanned" and uncontrolled actions. With the user scenario and the site, we introduced two new systems into the process. It was then necessary for the students to negotiate the spatial model with topography and user scenario.

Various techniques were used as planning devices. Different independent views from the structural models could be used to inform plan and sections. Sampling of geometry was another technique used by some groups. Other strategies involved a more smooth development of the model towards a building design. I will exemplify this last phase by presenting one case (Figure 128 to Figure 130). The student developed a suggestion for an art pavilion. In this case the model was used to develop both the formal organisation of the building and the activities. Different stages, involving manual drawing techniques and sketching, were used to interpret the model as a building.
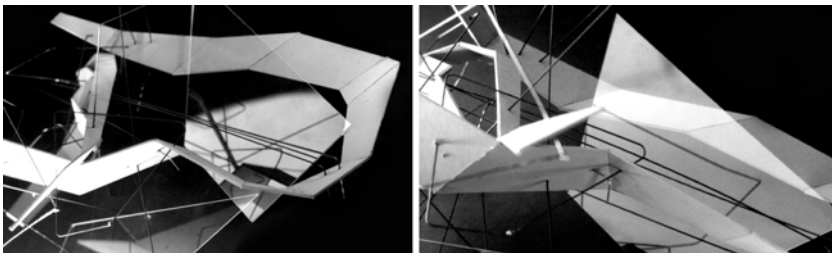
Figure 128 The interlocking between two systems allows new systems to be interwoven without jeopardising the global configuration. Here three systems are negotiated, a wire system a cardboard system and a Perspex system.
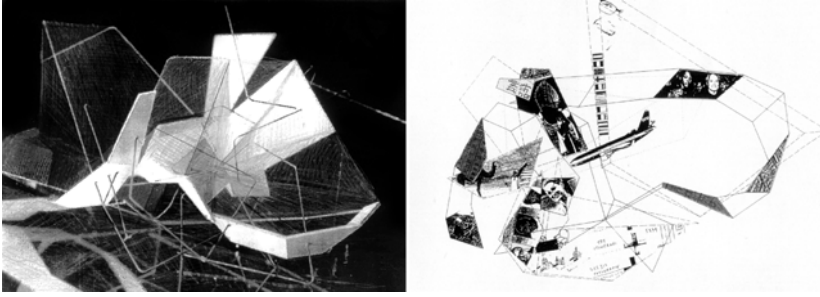
Figure 129 Development towards realization involves a stepwise interpretation of both formal solutions and the inhabitation. To the left: the model is developed towards a building by drawing on top of an image of the model. To the right: a sketch for a scenario of inhabitation is illustrated by placing / transposing /positioning a collage of activities onto the model.

A criticism of this project might be that the differentiation between the three systems in the model became somewhat blurred in the final design solution. On the other hand, the student reached a spatial configuration that was not informed by typologies. The design provides a series of spaces with different sizes and connections. This makes the design adaptable and able to tolerate future changes in the activities.

Program activities and inhabitation was hence treated in a loose way only suggesting a certain use of the building in the form of sketchy scenarios. The first step was to map images of activities to the geometries of the model (Figure 129). Later the program was indicated in plan and section (Figure 130).

In this workshop and at this stage of our investigation adaptability was developed as a formal concept. The results from the workshop were in some ways fairly superficial, but they opened up possibilities and techniques which inspired later developments of digital generative design. Another question is how one would approach these issues when building technology into account from the very beginning. On the one hand we have the intention of building adaptability into the geometrical features so that partly generic geometries allow for diversified use. On the other hand, we want to build adaptability into the material construction of a building. Recent work by DSRG, a group of architectural researchers has given some answers to these questions. (Hensel et al.)
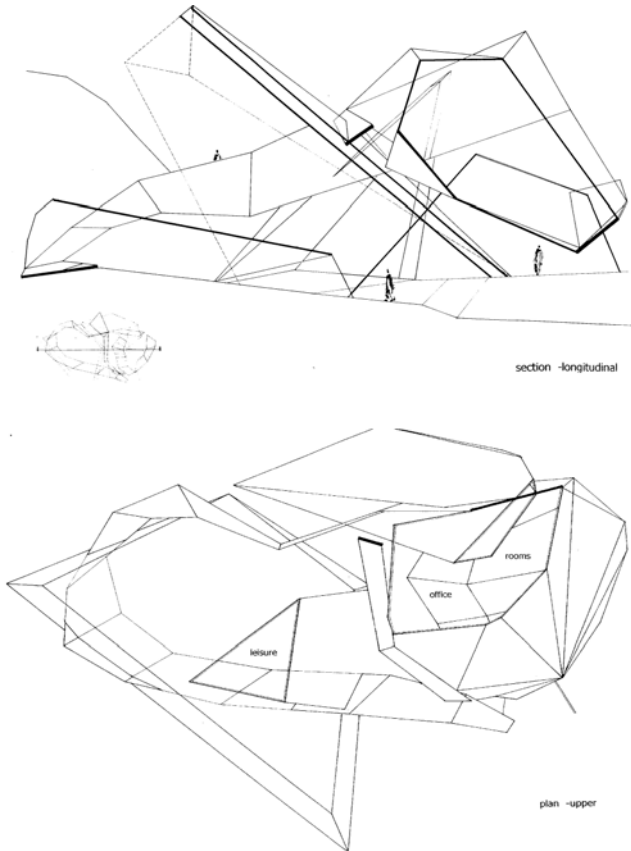
Figure 130 The resulting design has a configuration that allows for many scenarios of inhabitation. The spaces are not typical for their function. One can imagine alterations of the spaces and rebuilding of the construct without disturbing any finite composition.

Workshop as research tool

When we planned the theme and content of the workshop, we decided to choose the most interesting and difficult areas of our own work for further investigation. We had just finished another stage of the research project "Synthetic Landscape". This stage had left many questions unsolved. One of the major problems was how to implement and use the diagrammatic and abstract source material further in the design process; how to move from the abstract diagrammatic and structural to the concrete and defined design solution. This was a crucial point where we thought the workshop could help to develop both practical techniques and new strategies.

One of the most interesting objects for further investigation was the video "Virtual Phenomena" (Sevaldson, 1998). The road from dynamic generative diagram to final architectural design seemed to contain a wide range of possibilities, but how to proceed was unclear. Investigating these possibilities would involve considerable effort. The workshop was, for my part, seen as a kind of test field where practical solutions could be developed and tested. We did not know in advance what to look for, nor whether the students' findings would be of value. The emphasis was on the practical development of design strategies and the theoretical implications on the field of design.

From the outset, it was unclear what the results were going to be, and this open-ended approach was maintained throughout the study. In fact we were worried that our own prejudices would be too influential and bias the results. Biased results where apparent in two groups where some of the students were former OCEAN workshop participants or temporarily joining OCEAN projects. In the other groups the bias was less visible, though they too were considerably influenced by the tutors. The concern about biasing the results was in the end considered to be less important than the need for intensive tutoring and periodically detailed guidance of the students by the tutors. As the nature of the research in the workshops became clearer, the concern about biasing the outcome was reduced. The workshops should not be compared to laboratory settings where experiments have to be isolated from irrelevant influences. The research was an investigation in design practice. The students invented and developed practical solutions to advanced design challenges introduced by the tutors. In this sense the tutors were as much participants in the workshop research as the students.

The results from the workshops depended on post-investigation and analysis of the collected material.

Intentions to respond to dynamic environments through design - Time-based design.
The intentions behind working with time in design are:
- Developing an analysis of lifecycles, changes, future scenarios, system performances and the impact of action, forces and relations in a system
- Developing analyses of events and design interventions. (Event-based design)
- Working with timing, modulating intensities over time.
- Developing creative techniques.

The time-based approach leads towards understanding action, performance and life cycles. It involves working with time-based structures like

intensities, rhythms and repetitions. One central issue is timing as we find in music and film which is also relevant to user experience-related design tasks such as interface / interaction design and event-based design.

-Working with time helps to move focus from object to relations between entities, and how these relations unfold and form into complex systems of interactions.

- Developing creative processes: In everyday life we react in situations according to preconceptions of these situations. As long as a situation is fairly familiar we base our action on schemes built on experience. We forget how the world really works because we know how it works (schematically). These schemata help us to be efficient, but they also prevent us from being observant and innovative. These pre-conceived schemata can be modified or even broken through intensive observation of how an event actually works, which can result in creative responses.

-Learning generative design: Working with time means mostly operating on a structural level, avoiding semantics, metaphors and symbols. Design work is basically understood as a way of responding and influencing processes. The monitoring and analysis of the chosen events lead to innovation, in most cases not in the sense of targeting a problem and producing a solution, but more as a soft intervention that modifies a situation.

"The anatomy of movement".
Design with context-based source material.

In this study, the generation of the source material was tied to real-life observations or staged events. The observations were not used directly or as input parameters but were processed and diagrammed to generate a source material that was used in a design process. One could say that the real-life observations served as scaffolds for the generation of dynamic diagrams that were used as templates for the design process.

Intentions
The use of real-life events as the basis for source material for a generative process creates a relationship between the event and the design intervention right from the beginning.

We look at patterns of usage and try to influence them slightly. The role of design, in this view, is as an influencing force amongst many others. The designer induces certain conditions that influence the pattern of existing urban settings. In this case the role of the designer is not to radically change conditions or to disturb existing patterns of usage. Were that the case, the observation technique would be useless and we would have to use scenarios

or the generative techniques mentioned earlier based on grafting or other independent source materials, because the observed events would be removed and there would be no logical connection between observation and the generative process.

Relevant techniques:
Video monitoring, pattern recognition, working with timeline software, generative diagramming.

VORB 5

To clarify the difference between the process based on observation and found source material, and the process based on generated (simulated) source material, I will go through two basic cases before looking at a broader range of more advanced cases later.

The VORB5 workshops investigated the possibilities of producing geometries that were derived from captured motion forms with the assumption that such geometries would be suitable for inhabitation by similar related motions. This represents a shift in position regarding the source material. The source material was no longer generic and unrelated to the theme or issues of the following process, but it was derived from within the process. So in this case, a close relation between the source material and the field or theme of the project was present from the start.

The intention of this principle is based on the assumption that this approach would create a smoother process and that, from the outset, the source material would contain certain qualities related to the observed event that will be maintained throughout the process. Negotiation phases would be smoother. But this has larger implications since it not only introduces a generative process that starts from real-life sources but it keeps a relation to the real-life sources throughout the process.

The use of real-life sources in generative processes is old in art (Music Concrete) but in design this is less widespread[127].

A question that arises from this approach is whether such processes will produce less innovative solutions than when using a random or detached source material where the negotiation processes would be more laborious and would necessarily be forced to bridge bigger, logical and formal gaps.

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[127] Ben Van Berkel, Lars Spueybroek and other Dutch architects claimed in the mid-nineties the use of 'body-technique' – movement of human bodies in space as source material for such design processes.

In the workshop VORB 5, the source material was derived from the video taping of body movements. This was used to develop objects and environments in the scale of the body and in the scale of the interior. The first example was a project on the scale of the human body. [128] Its starting point was registration of body movement and its result was objects on a furniture scale. The collection of source material was based on video taping of staged body movements. An actor (one of the students) performed in a dark space. The movements intuitively resembled some typical or generic movements of the body that the students found interesting, and which they regarded useful for further development. This could be transitions between typical body positions e.g. the transition between standing and lying down which potentially could initiate furniture-spaces for body positions other than the typical ones (standing, sitting lying). In addition this technique has the potential to depart from the typical sitting and lying positions and investigate new variants. The actors in some cases used semi-transparent textile "costumes". The textiles rendered a close dynamic space for the body movement. This was a generative technique that created a design space around the body, which helped to articulate the relation between the body and the surrounding space. The textiles served as a scaffold or negotiation device between the body and the suggested design solutions.

The next step in the process was graphical manipulation and processing of both video and still images of staged movement. Line geometries where derived through graphical filtering and manual tracing of construction lines (Figure 131).

From the manipulated material, the students built two diverse series of physical models. Building physical models totally changes the perspective with respect to the source material. The change in media forces a new analysis of the material and the processing takes new routes. In this case two different approaches where tested.

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[128] Conceptual Design , Oslo School of Architecture IFID 2000. Bergem Anne Lise, Heidi Devik Ekstrøm, Hanne Marte Holmøy, Heidi Susanne Leren
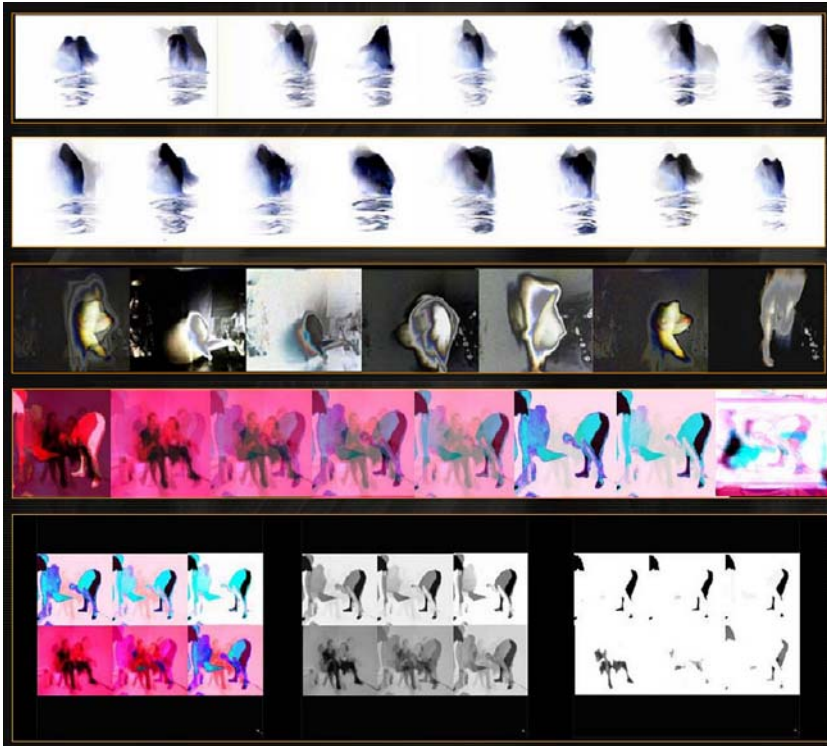
Figure 131 Various filtering methods. The three top rows show video footage that is manipulated with contrasting and blurring filters in Photoshop to derive different possible "event envelopes" from the body movements.
Lower two rows: alternative graphical treatments where juxtaposition and colour filtering are tested. (Images from students' web-presentation)

In the first model traced lines from the filtered video material were used to draw silhouettes of the event envelope. The filtered material (image above, row three) provided in some cases clear colour gradient isoparms which were useable for manual or digital tracing. A selection of frames were used as underlay and the resulting silhouettes placed along a timeline. This allows a close study of the spatial relation of an event. The model represents a frozen time-span which can be investigated simultaneously along the whole span of time, without being dependent on memory. Relations and diversities between the time-sections, representing evenly distributed moments along the duration of the model, can immediately be spotted and analysed.

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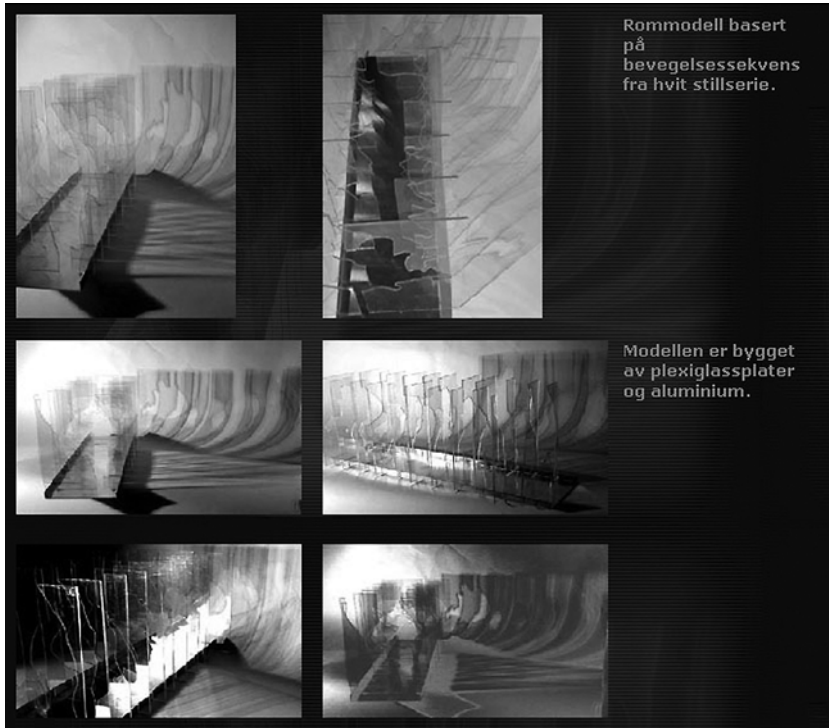
Figure 132 Physical Perspex model based on trace lines derived from graphical manipulation of the "event envelopes". Each layer of the model represents a time-section. (Images from student's web-presentation)

This type of model was developed both with opaque and transparent materials (Figure 132 and Figure 133). The templates for the two materials were derived from two different series of manipulation of the same source material. The first series for the Perspex models rendered a wider space (event envelope) than the second series used for the balsa models. This indicates two levels of near body-space, which could be treated slightly different in a further design process.

Samme rommodell kombinert med bevegelsessekvens fra rød stillserie.

Rød stillserie er i modellen visualisert gjennom bruk av balsatre.

Figure 133 Perspex and balsa model of the event envelops (Perspex) and the space closest to the body (balsa) (Images from student's web-presentation)

In the second model series images from the manipulation of the source materials were printed on overhead foil and mounted along a time line, each image representing a time section, similar to the former model, (Figure 134). This allowed a close study of time-space relations in a similar way to the former model. While the former model allowed an immediate overview along the whole depth of the model, the second model was much more detailed which limited the depth view along the time axis. This type of model provided more detail and nuances at the cost of global overview.
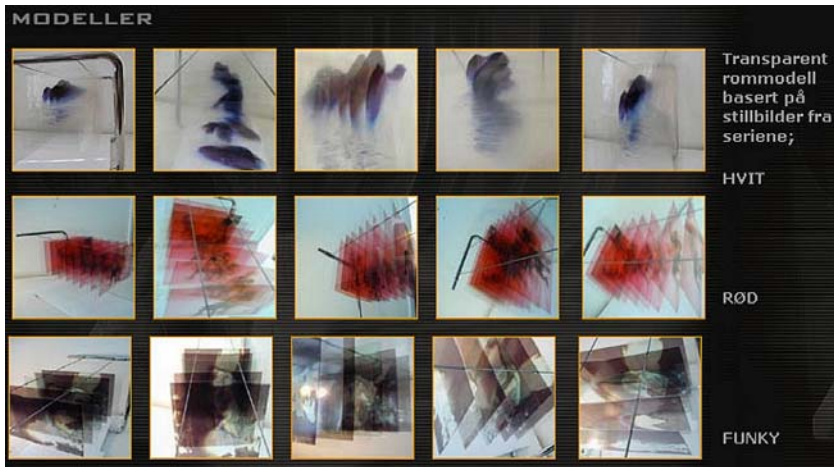
Figure 134 Model of time sections printed on overhead foil. This model supported a much larger degree of detail at the cost of transparency. (Images from students web-presentation)

The students developed a final design proposal derived from the movement studies and synthesises. (Figure 135).The main strategy in this process was sampling, where parts collected from the different models were extracted, modified and mounted together.

The end result was an inhabitable space divider that would offer the support for a great variety of leaning and sitting positions. The space divider was built up along an axis system that resembled the time axis in the models. By mirroring and repeating a short section, they managed to decrease complexity while maintaining the use-potential.

This project developed a series of practical techniques that contrasted each other. It demonstrates the importance of media and media change, and also how the development of different modes of representation can enrich the understanding and analysis of a complex material. The final solution shows some interesting strategies for balancing the amount of information in a complex design. This involved developing a module system around the complex geometries. This is interesting because most often module systems and complex geometries are regarded separately, complexity usually being achieved through the combination of relatively simple units. The final solution is underdeveloped and it would be interesting to see further refinement. The interesting aspects of this example rest in the way the observations and registrations were captured and developed into refined models.
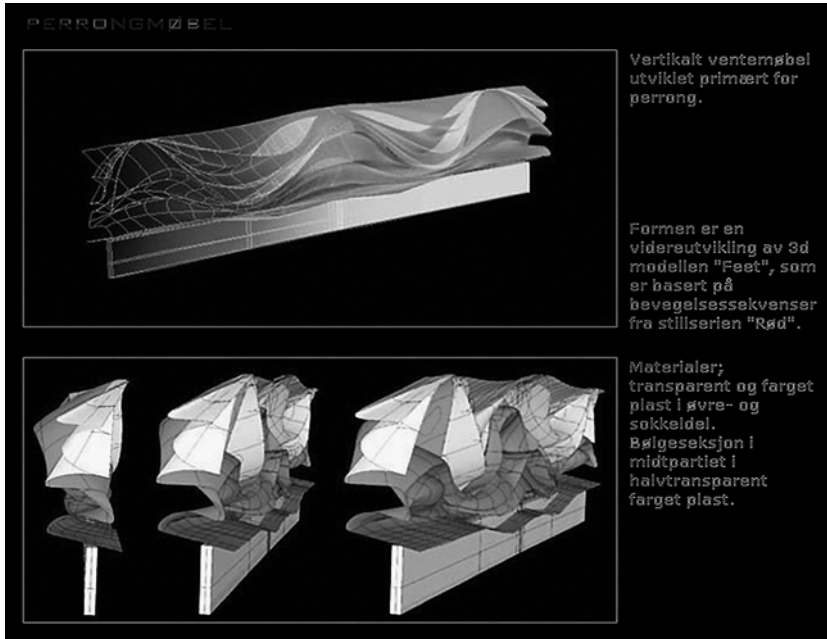
Figure 135 Sketch of inhabitable spatial divider or "resting wall" designed with the preceding models as input and templates. (Images from students' web-presentation)

In the next example, a waiting lounge for a ferry company in Oslo, the source material was not found in real life but simulated. This is a departure from the observation perspective and it implies a position somewhere between the generic generative and the contextualised source material. The reason for this was that the initial observation showed a pattern of spatial behaviour that was too strongly influenced by the existing interior. This interior was seen as unsatisfying and it needed to be totally replaced with something that would influence the passengers' inhabitation of the space in a less determined way. There was no way of influencing the patterns of usage of the space without totally changing the existing configuration. Still, certain phenomena were registered and the intention was to implement these in the new design solution. Amongst these were occupational behaviour: how the travellers occupied space and how occupation behaviour and territorial negotiations were different when the space was sparsely populated compared to when the space was crowded. Similarly, observations of communication and contact between travellers were recorded.

In this case a particle animation was used to simulate the main trajectory of the traffic through the emptied space of the waiting lounge. The interesting issue here is that this was a simulation of abstracted movement through the

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space but it was absolutely not a simulation of movement of real travellers through the space. The simulation just articulated potential speculative movement with the same point of entry and departure as the travellers would have. The reason for this choice, was that the student wanted to generate a diagram of movement that was more detailed, random and articulated than a simple diagram containing an arrow pointing diagonally from the entrance to the exit of the lounge. The use of a realistic simulation tool was abandoned for two reasons: first we did not have such tools available. Second and more importantly: these tools are often based on e.g. fire escape calculations or similar escape needs. The main parameter (to escape a facility) overshadows other possible parameters (shopping, eating, sitting). Only to a limited degree do they simulate random movements in the space. Such random use of space is most apparent in waiting situations. An additional consideration was that the simulation should not necessarily simulate the most likely use of the space but rather a broad range of variations of usage that at a later stage could be used for the construction of scenarios. Unlikely use is sometimes more interesting and potentially more useful as input for design when trying to create adaptable spaces.

The particle animation was used to articulate the lounge into various zones of intensity from long-term waiting to last-minute arrival (Figure 136). Areas of highest particle intensity were read as shortest-term use, like the diagonal route directly towards the ferry departure exit. Lowest intensity areas were coded for longest term waiting like for people who want to take a nap while waiting for hours, similar to what often happens on airports. The space was organised in levels where the highest level was for longest-term waiting, creating a "valley" for the fastest track leading directly to the ferry departure exit. The particle animation was used to articulate the level edges in a way that created conditions for occupation and the establishment of temporal territories through inhabitation. [129] The geometries were tested with the aforementioned scenarios. All kinds of inhabitations of the space by different users were imagined. The negotiation process which followed resulted in a substantial altering of the formation of the levels.

This project shows the importance of the way in which context-based source material is generated. In this case the source material was a simulation that was set up after observing a real space. The observation resulted in a decision to dismiss the existing interior and to replace it completely. The observation was therefore not suited to inform a redesign of the space. In cases where the real-life events are strongly restrained by existing spatial geometries that are going to be replaced, it makes less sense to base a redesign of the space on real-life observation.

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[129] *VORB 5 Oslo School of Architecture IFID 2000. Ksenia Movafagh, Mette Hustad, Morten Kildal, Lars Kløve Bjerke*
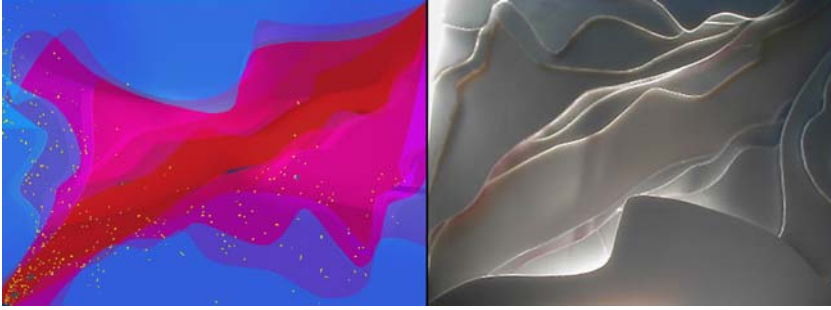
Figure 136 Two plan views of ferry terminal waiting lounge. The entrance is in the lower left corner, the exit to the ferries is in the upper right corner. Left: Plan view of digital model with particle animation and derived initial sketch of the waiting lounge. Since only one frame of particle animation is shown, the relation between the animation and the resulting form is not obvious on a still image. Right: Plan view of physical model with lighting beneath steps. The difference between the initial sketch and the final model shows the result of the scenario-based negotiation process in the later design phase.

When total replacement of the situation is likely, these observation techniques have to be used in different ways. They can be used as analysing tools but not as generative source material for a radical intervention because they are based on a situation that is going to be substantially altered. This implies that a greater degree of generalisation and processing is needed. The material from the observations can inform a simulation that produces a generative source material for a new situation, as shown in the last project.

Designing Time

Designing Time is the name of an experimental design course at the Oslo School of Architecture taught over a period of three years (2000 to 2002). The participating students were third and fourth year Industrial Design Students. The studio is concerned with time-based design. (Sevaldson, 2001b, Sevaldson, 2000a)

The course serves as a laboratory to invent, develop and test strategies and techniques relevant to time-based design. The students work in a wide range of fields and themes and they combine the above-mentioned techniques and include new techniques and traditional drawing and modelling in complex and complete projects.

Working with time helps students to develop the ability to investigate relations and systems and to understand these through time-based analysis and abstraction. We introduce the students to time-based thinking by starting

with observations of real-life phenomena. The students develop registration and analysing techniques involving a wide range of tools and means. The observations lead to discoveries of opportunities for intervention and in some cases innovation.

Intentions
The studio project has several learning goals. Many of the learning goals draw on the earlier experiments and systematisation described in the essay "Ways of Working". (Sevaldson, 2004)
The learning goals were:

-Moving focus from object orientation to system thinking.
Working with time helps to move focus from object to relations between entities and how these relations unfold and form into complex systems of interactions.

- Learning to work with time-based structures.
The time-based approach leads us towards the understanding of action, performance and life-cycles of objects and environments. It involves working with time-based structures like intensities, rhythms and repetitions in e.g. patterns of usage or the occupation of spaces. One central issue is timing. Music and film pieces are analysed to understand how other professions consciously work with timing. These rehearsals are especially useful for all user-experience related design tasks like interface / interaction design and event-based design where the design and timing of a user experience is central.

- Developing creative processes.
In everyday life we react in situations according to preconceptions. As long as a situation is fairly familiar we act from schemes built on experience. These schemata help us to be efficient, but they also prevent us from being observant and innovative. Intensive observation can help us to rediscover the world, which can result in creative responses. The monitoring and analysis of the chosen events lead to innovation, in most cases not in the sense of targeting a problem and producing a solution but more as a soft intervention that modifies a situation.

-Learning generative design.
The *Designing Time - studio* is more concerned with structural issues than semantics, metaphors and symbols. Design work is basically understood as a way of influencing and responding to processes. There is no design brief or problem to solve in the initial phases. These have to be developed during the process. They are derived from the observation and the design is regarded as an intervention that slightly influences an existing system over time.

Relevant techniques
Video monitoring and other observation techniques including graphic filtering and pattern recognition, descriptive and generative diagramming, generative design and traditional design, and all kinds of modelling techniques depending on the project development.

Method and Project Structure
In *Designing Time* the students develop their own design methods and techniques. The aim is not to teach design methods as such, but to implement an altered perspective on design which nurtures new ways of thinking. The student is confronted with very few guidelines and limitations and input. Only a generic framework is given.

The three major elements in the framework are:
-observation
-analysis
-intervention
The framework avoids preconceptions of problem areas and inventions to solve them. This ideology challenges both the conception of the designer as a problem solver and as a stylist.

On the basis of the observations the project develops smoothly towards a process and methods which are individual and vary according to the nature of the projects. This approach teaches the students how to develop their own design processes.

The three main elements are not strictly phased, with one exception. The students are not allowed to jump to solutions derived form quick associations. This resistance forces students who are brought up in a problem-solving and idea-based tradition into a generative design process where they have to respond to observations and analysis. The area of interest is chosen by each student on the basis of personal interests and preferences. The students start with collecting information through observations. The collected material is translated into series of structural or diagrammatical models. These models help to clarify the nature of the observations and create a smooth transition towards an output that would modify the setting.

The projects develop along several paths:
- The observation of movement as such in the continuation of Marey's experiments. (Braun, 1992)
- The observation of the behaviour and performance of singular objects with emphasis on the relations to interacting entities (other objects, people) over time, during the unfolding of a process.
The observation of complex situations with emphasis on the discovery and analysis of patterns in the interaction between entities and environments.
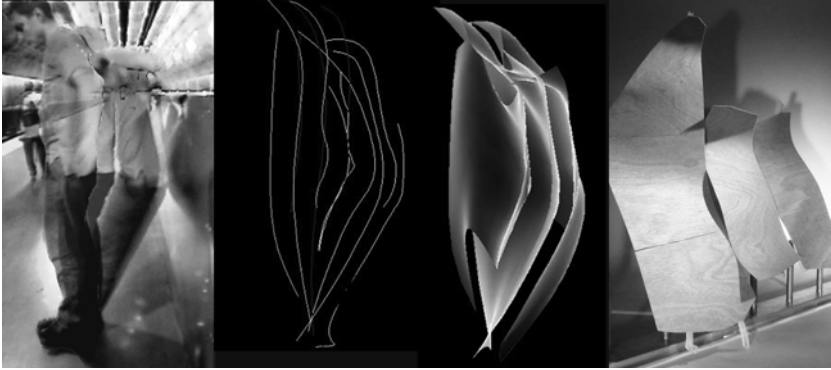
Figure 137 A smooth process movies from observation of the body-related use of a train station waiting area towards furniture for waiting. (Jens Pettersen and Lars Bjerke)

The means include:

Registration techniques: Sketching, storyboarding, video, still photos

Analysis: Visual analysis through sketching, systematisation, pattern recognition, text, codification and categorisation. These issues have been treated earlier in an earlier essay. (Sevaldson, 2001c)

Simulation: Reconstruction of simulation models in studio settings or animation software packages

Abstraction: Diagramming of time-based processes. Diagramming is any technique to reinforce the display of certain features of an observation at the cost of others.

The results derived form these studies include:
- Time-based installations and visual material, digital and physical models.
- Invention of devices to monitor activities.
- On-site soft interventions.

Observation

Observations frequently lead to distinctive discoveries. Even monitoring one-self will reveal new unexpected experiences. One student did an observation of himself cooking a bag of instant noodles. He discovered that there are a minimum of seven to ten containers involved in the seemingly simple operations. The schematic preconception of this process is so strong that normally people do not believe this statement before we start to count.
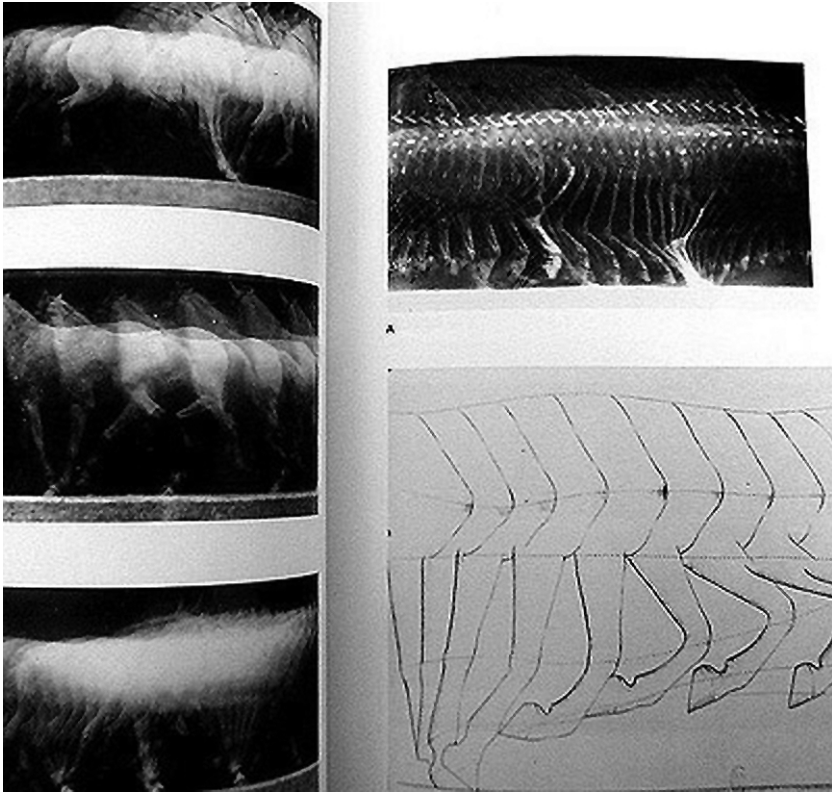
*Figure 138 Etienne-Jules Marey the pioneer of movement. The example shows a study of the movement of a horse. (From Marta Braun's book on Marey, Picturing Time(Braun, 1992))*

I have repeated this example many times and most often people guess that there will be two ore three containers involved. They have such a strong preconception about what is happening that it influences their perception. The example is very interesting because it demonstrates that we do not only have schemata about singularities but also about time-based processes even those which are not repeated very often. The counting of containers involved show that the number of containers is never less than five: the cabinet where the noodles are kept, the plastic bag with noodles, the included bags of herbs, the drawer for the spoon, the spoon, the cabinet for the pot, the pot, the cabinet for the bowl, the bowl, the sink for washing up, the soap dispenser..... Mapping the relations over time between the objects reveals a complex pattern.

In other cases the discoveries are less particular but nevertheless equally important. The observation of complex urban spaces ideally leads to a deep knowledge of the pattern of occupation and activities of public spaces. The observation of natural phenomena like running water or the sunlight during one day train the students' ability to find collect and reuse graphical samples in a design process.

Since Marey's experiments, the invention of digital graphical tools have changed the conditions dramatically and opened up new possibilities. Despite these possibilities there have not been many similar experiments to those done by Marey. The Designing Time course intends to utilise the computer in the analysis of movement. The computer is especially useful to investigate phenomena that are difficult to observe because of the time-scale (changes which are either too quick or too slow). With the computer the time-scale can be manipulated to reveal patterns and phenomena that are otherwise hard to discover. The computer is also well suited to graphically enhancing and changing the registered material to make certain issues more perceivable (Figure 139).
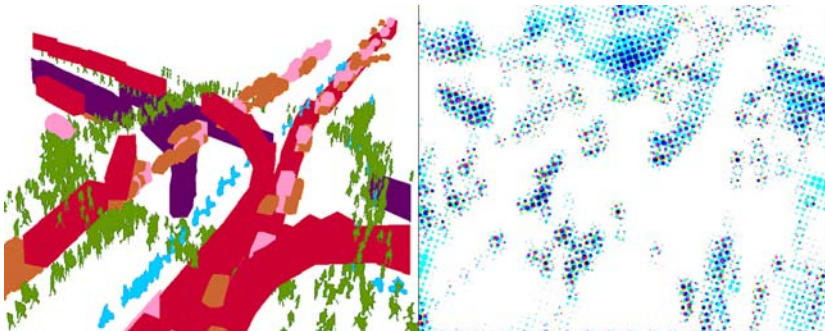
Figure 139 A small public square in front of the Oslo City Shopping Mall. Careful observation established categories and patterns of use. These patterns seemed to be quite complex including several types of pedestrian behaviour and waiting behaviour, like waiting for social reasons or for transportation. Also these patterns and their relations changed during a 24 hr cycle. The complex material was only possible to investigate through diagrammatical visualisation and visual analysis. (Ambjørn Viking)

From observation to analysis and intervention.
Digital video and related time-based techniques can be used not only to report and register real-life events, but also as an active design tool. Video monitoring helps us to see time-based patterns such as repetitions, rhythms, intensities and trends. Often the raw footage has to be processed to make

patterns visible. The patterns might be hidden from direct observation because they are distributed over a time-span that is not within the time-scale we normally can observe directly. By manipulating the time-scale, slowing down or speeding up the video, these patterns can become directly visible. These are techniques known from the observation of natural phenomena like the growth of plants. In other cases patterns are invisible because of the complexity of the situation, where the elements we want to observe are obscured by other elements. Diagramming techniques can also be used on moving images with software like After Effects to make these patterns visible. Other time-based manipulation analysis include time collapsing, stretching, reversing, "scratching" and "sampling".

Reinforcing and "cursoring"
Marey invented several techniques that made it easy to investigate fast movements in detail. In the observation of a human model jumping off a stool he used white cursor points to make it possible to follow the movement. The model is dressed in black and the room has a black background to make the white cursors more visible.
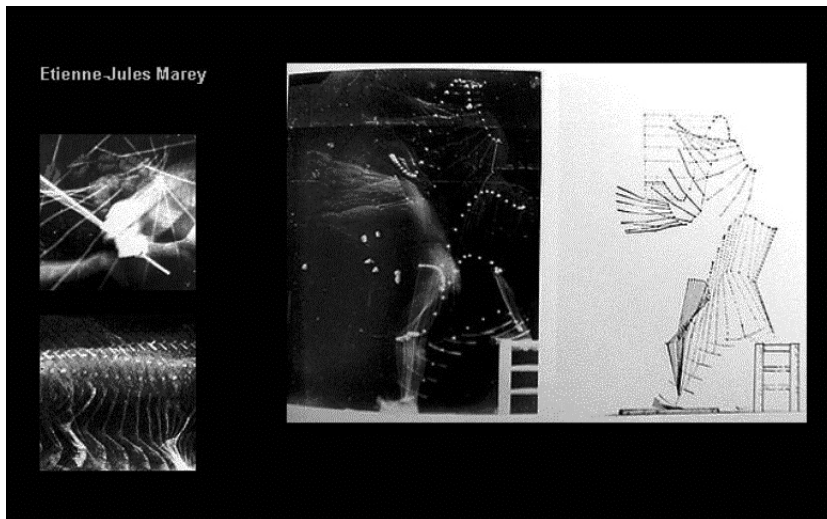
*Figure 140 Marey used cursors in staged settings in experimental studios to clarify and emphasise the nature of the observed movements. (Images from Marta Braun's book on Marey, Picturing Time(Braun, 1992))*

In the shown example Marey introduces diagramming techniques both before and after the captured moment. Before capturing he prepares the stage set, the dark background and dress, visually removing elements that are of less

interest, and using the white points to emphasize elements that are of interest. After the shot he analyzes and clarifies through diagrammatic drawing where he also relates the cursor points by connecting them with lines and establishing the spatial relation between the points at all moments. These lines depict abstract structural relations because they do not exist in any form other than as a conceptual construction; the product of an analysis. Nevertheless, they are real in the sense that they are exact and reconstructable features of the real world.[130]

Digital Marey
In an initial study with a digital doll and several digital cursors, I tried to investigate the potential in the continuation of Marey's work but now with the new possibilities that computer technology offers.
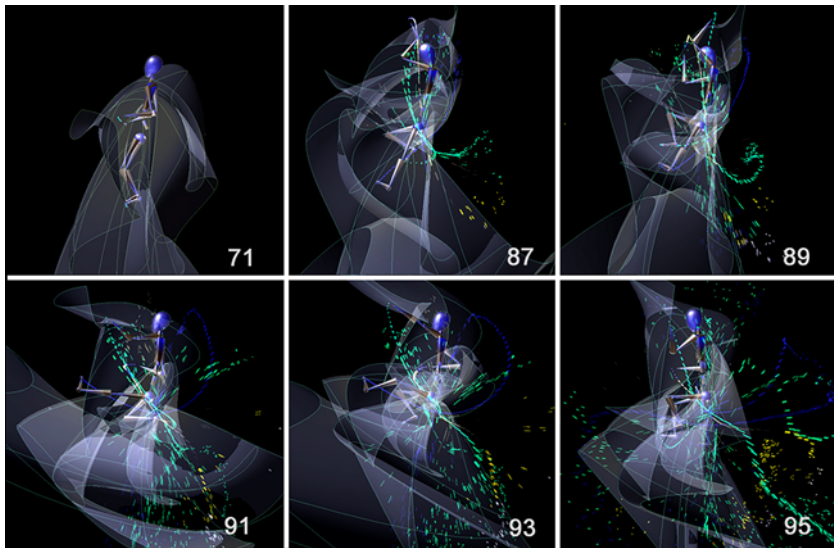
Figure 141 Virtual doll surrounded by deformed spherical surfaces and particles that together render an enhanced design space for the doll. This space is a abstract articulation of the space between the body and its surrounding. This articulated space could be used in the design of clothes, furniture and small interior spaces.

Starting with a virtual doll in 3D software (AliasWavefront Studio), the doll represented a generic body movement which was meant to contribute to the initial articulation of the territory surrounding the doll. Three deformed spherical surfaces surrounded the doll. The skeleton doll and the surfaces

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[130] This is related to the technique of 'notation' as used in dance and choreography.

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were linked according to a non-significant intricate system (Multiple clustering of control vertices). Non- significant means that there was no other rationale in the linking than a local similarity or spatial match between the clusters of control vertices and the respective skeleton nodes the clusters were linked to.

The doll was animated according to typical, but, at the same time, articulated movement from standing position to sitting and laid back position and back to upright standing position. This was meant to render a smooth scale of transformations through a range of possible leaning and seating positions. When in standing position, the body only influenced the surrounding space rendered by the deformed spheres to a very limited degree. During the transformation from upright to laid-back position, the abstract spatial rendering was increasingly influenced and transformed and through this, seamlessly modulated into a more articulated but also less abstract stage (Figure 141). In the most extreme laid back position, when the body would be the most dependent on support, the blobs could almost have been used to directly inform furniture structures.

This whole transition from the standing to the laid back position also rendered a seamless transformation from the unarticulated, generic / abstract to the articulated, specific and more concrete formal representation. This was emphasised through an additional detailed articulation of movement, a twist and asymmetric movements of the arms which were most significant when the doll was in its most laid back position

The analysis and study of similar illustrations and sculptures initiates three levels of operation related to the design of the human body's immediate surroundings. A close-up micro-level was introduced, which could inform material conditions such as clothing or tools, or even furniture, in more detail than in the initial animation. At the other end of the scale, a third animation set-up was initiated which would expose the doll's territory to external forces, an animation set-up informing us about the scale of the room (interior-spatial).

In the *Designing Time* projects, the students developed similar reinforcement techniques that were partly based on staging and partly on the use of computer graphics. Similar spatial devices as the surfaces in the above animation where created through the use of textiles. The textiles disguised the body and generated numerous potential envelopes for movement and design. (Figure 142)
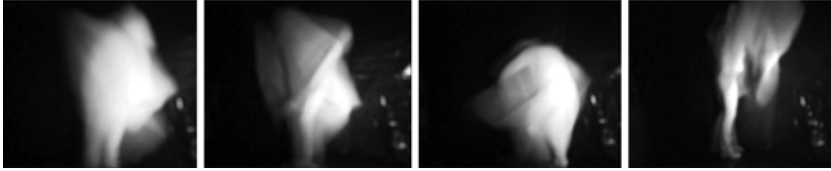
Figure 142 Staged experiments with textile, light setting, time-manipulation of the DV-CAM and digital processing in Photoshop or After Effects. (Anne Lise Bergem, Heidi Devik Ekstrøm, Hanne Marte Holmøy, Heidi Susanne Leren)

This marks a principel shift from the experiments of Marey. shift from the experiments of Marey. Whereas he observed the nature of movement as exactly as possible and in the sense of the scientific experiment that can be repeated, the observations in our studios were concerned with variation, and patterns in these variations. From observing the patterns, we formed an overall picture of the rhythms and the nature of the events. This enables us to move away from Marey's schematic or fragmented experiments and work with real-life movements or intuitive responses in more complex and variable events.

These techniques were not consciously derived from Marey, but the link and relation to his work became obvious and was investigated in depth later.

Self-monitoring.

Video is a means of collecting raw data very quickly but it requires a great amount of subsequent work. Some aspects of the work which we used to have to deal with after filming can now be taken into consideration on site. This reduces the amount of editing work later on. Other media like traditional drawing techniques however might demand even more intense on-site analysis, which in certain settings is an advantage.

Despite the digital techniques that were available, traditional drawing techniques were regarded as being very useful. Indeed, the different techniques supplement each other. Comic-related techniques and storyboarding are well-suited to self-monitoring and the monitoring of objects. A brilliant reference to the techniques of the comic-strip is Scott McCloud´s book Understanding Comics. (McCloud, 1994) Since the whole book is written in the style of comics, it simultaneously describes and illustrates the issues it analyses.

Self-monitoring has frequently been discussed by e.g. Donald Schön (Schön, 1982) and also criticised for the bias it introduces in interrupting the creative work flow through observation. In our case we were investigating typical everyday events from real-life which were considered to be quite "automated", like brushing teeth or making a cup of tea.

The observed event is of course influenced by the introduction of real-time observation techniques (registration and reflection in action and even drawing in action!). But in these cases, where robust everyday activities were being observed, rather than fragile creative processes, bias was actually an advantage. The techniques deliberately changed the conceptual state of the performer/observer to create a new level of awareness. This level of awareness helps the observer to 'rediscover' a known event which in our mind has become a schemata. Repetitive actions become schematic and we forget about the complexity embedded in them.

Analyses
During and after monitoring, the students analysed the material. There was an emphasis on finding distinct phenomena and on recognising patterns. The students had to invent and develop visual analysis, methods and techniques for their cases. They could use digital filters such as blurring, sharpening, contrasting and colour separation in Photoshop and After Effects (Figure 144).
For time analysis they could use video editing tools or other software with time lines (e.g. Maya or Flash). They found time-based patterns through manipulation analysis like time collapsing, stretching and reversing.
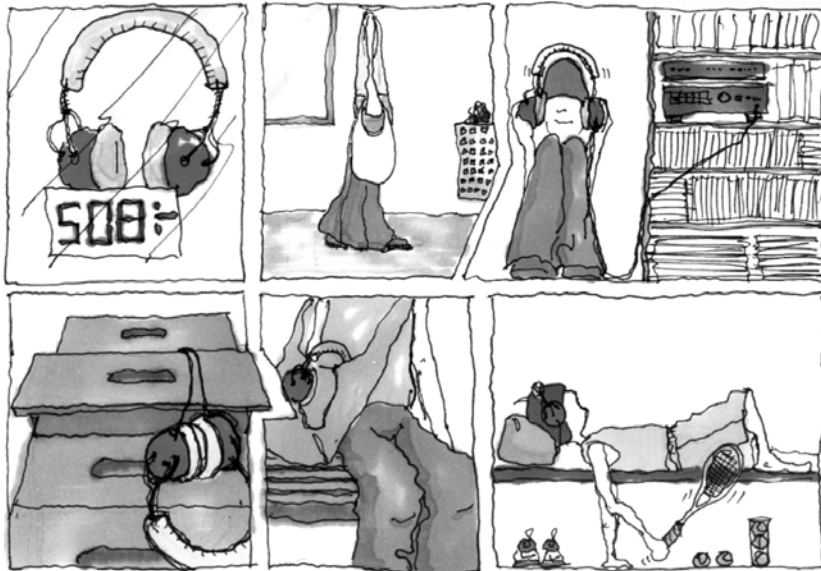
Figure 143 Using comic-strip related techniques to monitor the use of an object. (sketch by student Ambjørn Viking)
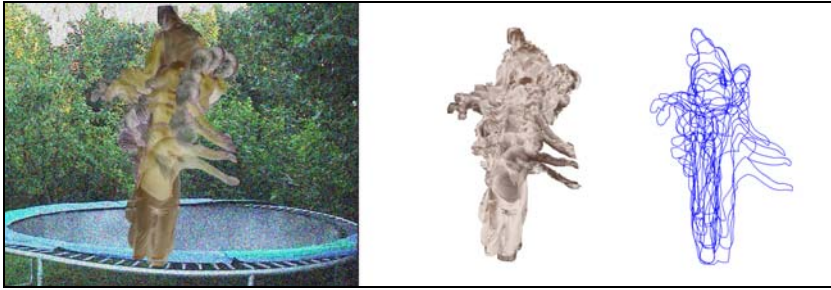
Figure 144 Visual analysis of movements on a trampoline. From Photoshop to flash. The student intended to capture the shape of movement first by double exposure technique and then by a graphical treatment that transforms the captured movement to a more abstract representation. This clarifies the form of the movement.

Diagrams and theory

The analyses produce an output which is more or less diagrammatic. Sources for inspiration are scientific visualisation, Edward Tufte (Tufte, 1983), but also generative diagramming as described earlier in this thesis. The diagrams produce the basis for the categorising of phenomena. Categorising of found phenomena helps to evolve theories about the observed real-life processes. This relates to for example grounded theory described by Glaser and Strauss (Glaser and Strauss, 1967) and others.

Figure 145 Diagramming real world: All kind of data was captured with no regard to potential use. This technique highlights issues about the real world that normally would have been unexplored.
To the left diagram of waiting time superimposed on site. To the right the registration of the colours of pedestrians jacket during one hour.

Interventions and inventions
On the basis of the monitoring process and the analysis, the students were
then asked to find an intervention that softly modulates or describes the
observed event. Understanding the patterns of relations should make it
possible to softly modify them or to express them through a media of own
choice. A soft modulation or intervention is used here to describe a design
intervention that does not alter the main use or functionality of a space or an
environment, but that alters it on the detail level.

Examples of the students' works are: a video installation in cafe
environment; a complex shelter in a public square; a sculpture of a
snowboard jump; an advanced kitchen timer; flexible territorial furniture; a
soft modulated waiting area; and a sculptural art piece at a dock side that had
functional features serving as furniture, lee-wall and territorial divider
(Figure 146).
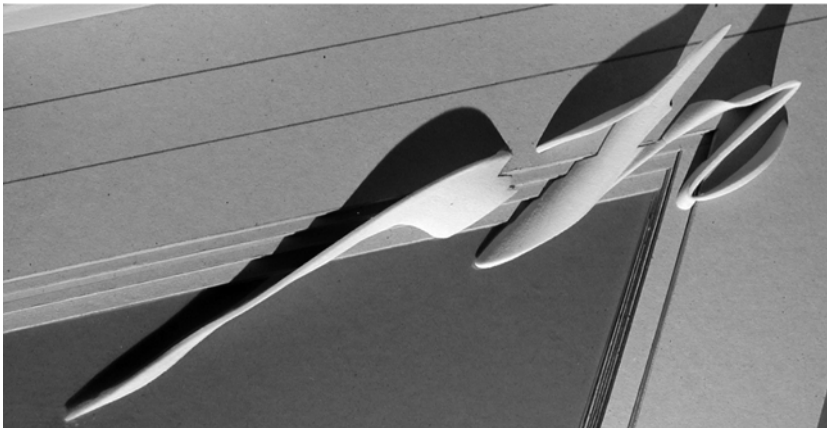
*Figure 146 What could be taken as a sculptural art piece is actually a modulation of
a dockside to provide a richness and variation of spatial possibilities to the public.
The installation is derived from patterns of usage at the site. It combines the features
of a lee-wall with those of back support and territorial division. (Are Nielsen and
Lina Aker)*

Cases
Case 1: Dinner in 60 minutes.
This case is exceptional because it leads from observation to a problem
definition and a solution to the problem. But the solution regarded as design
intervention is still a soft intervention, that does not radically change the
patterns of behaviour, but that helps to refine and time these patterns.

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The solution was smoothly derived from the observations and the diagramming of the behaviour patterns. In this case the student, Mari Honne Enge, started with several observation rehearsals, amongst others the pattern of movements of hands of a group of people cooperating on solving a jigsaw puzzle. This starting point triggered the student's interest in short-time events with a high degree of relational complexity.

Figure 147 To the left: Video monitoring of a cooperation task.
To the right: still image collage depicting the complexity of preparing a meal.

The observations were moved to the student's own everyday situation in her kitchen, investigating the high degree of complexity in the relations between human, objects and furniture pieces during cooking a meal. This complexity was captured with stills, video, sketching and diagramming. An accurate timeline-based diagram was produced to get an overview of the process (Figure 148).
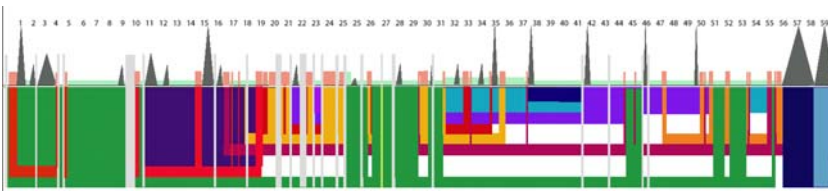
Figure 148 A timeline-based diagram maps the complex activity of cooking a meal.
Above the horizontal line are all the activities that are directly related to activities at
the cooking stove. The grey peaks indicate the starting of cooking processes. The pink
columns indicate stirring and monitoring. Below the line are the preparation
activities where each colour is mapped to different components of the meal. The
diagram demonstrates what an immensely complex activity cooking really is and how
important the issues of timing are.

The next step of analysis included a stylised digital simulation produced in Flash. This simulation helped to clarify the sequencing of the tasks (Figure 149). The timeline diagram directly inspired and informed the invention of a new timer for complex parallel time-based processes. The timer was simulated in Flash (Figure 149). The timer is programmable with multiple parallel timelines, one for each cooking activity. The timer warns the cook when to start a process and when to finish it.
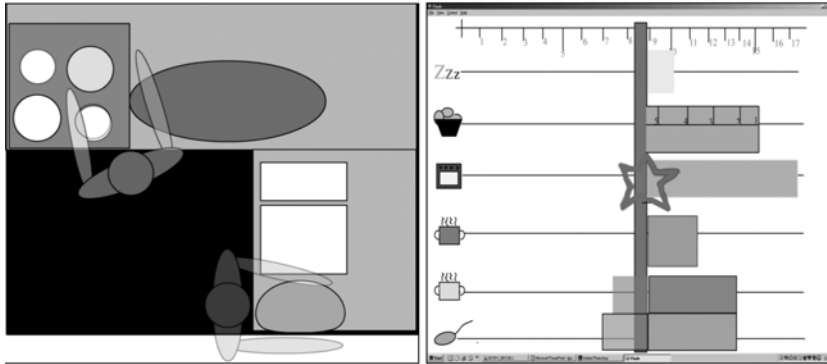
Figure 149 To the left: Screen capture of the flash simulation of the use of the kitchen. To the right: Flash prototype of the timer captured in the moment when the alarm for starting the stove is triggered

In this project the diagramming of the events turned out to feed directly into a device that was a response to the analysis of the sequential and parallel operations of cooking a meal. The timer is in itself a dynamic real-time diagram designed to help timing in any complex task. In this case it was used to get all the cooking processes timed right so that e.g. the fish does not get cold before the potatoes are cooked.

Case 2: Form derived from movement patterns.
Some students worked in a very direct way where they used the shape of movements as design input. The following example is one that demonstrates the soft intervention to an existing behaviour pattern. This example is successful in the sense that it does not impose change in any way with forced means, but at the same time the suggested solution is so strongly influential that we can assume that the pattern of use would probably change considerably. The combination of an unforced but still powerful intervention is especially interesting.

In this example by Ambjørn Viking, a square outside a shopping centre in downtown Oslo was observed. He used several different layered diagramming techniques for the analysis of usage of the space (Figure 150). The diagrams slowly developed the understanding of the patterns of use and also an understanding of how to intervene.
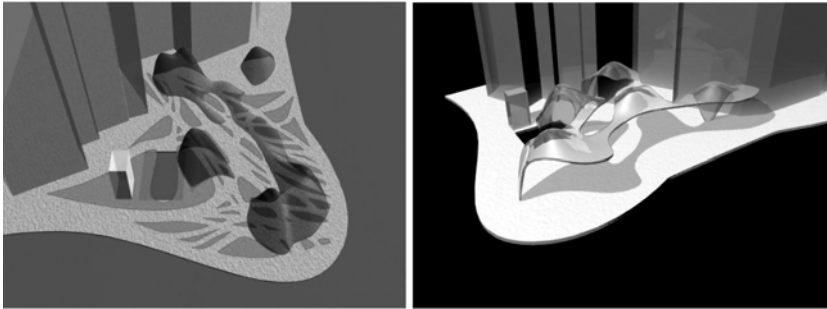
Figure 150 To the left: Pattern recognition: Diagram of activities outside a shopping centre in Oslo, showing the still areas least influenced by pedestrian paths (pink) and the most intensely crowded areas (blue). These are only two of several other ways of diagramming the space. To the right: Suggested intervention that softly modulates the crowding behaviour. (Ambjørn Viking)

An intervention should grow out from the visual analysis and hence from the real-life events on the site. Therefore the intervention did not intend to reorganise the site entirely but rather softly modulated the attraction forces on the site. This was done very simply by providing a shelter that had a form that was engaged with the existing patterns of use. The shelter provided varying attraction forces according to daytime, year or weather conditions. It did not force the patterns into new forms but offered new qualities to the site and suggested a sorting of waiting and walking areas, though the borders between these activities remained blurred and flexible.

Case 3 Café Table Installation. Modifying social space.
In this last case, the student intended to depart from using spatial geometries as a means to influence a space. Instead, her field of investigation was the social space as such. Based on observations of the use of café tables, she used digital technology to influence the relations in the social space of the cantina at the Oslo School of Architecture.

In this project, the starting point was activity at cafés in an area in Oslo. The student, Silvia Lesoil, frequented several cafés and applied a long range of laborious observation methods. Amongst these were hand drawing and even

video, which was difficult to organise in an indoor public space. The analysis soon focused on the social space provided by the café in general, and on a smaller scale, the café. The student started to analyse territorial occupation and interaction between the guests on the scale of the whole café and on the table surface.

Based on the observations, the student developed a concept for a video installation that would play with and diffuse or reinforce these issues visually in a cafe setting. The installation transmitted video between tables projecting the actions from one table onto another.
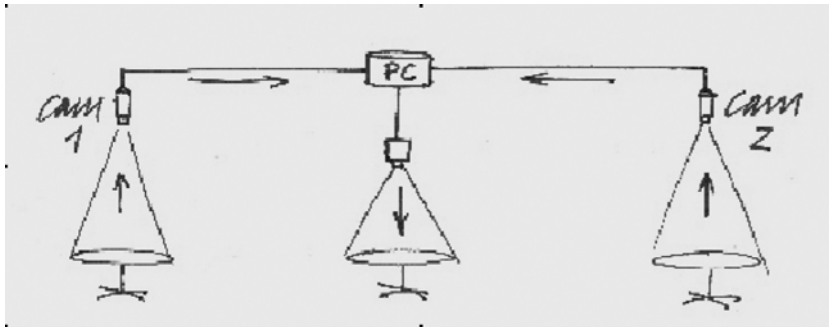
Figure 151 Diagram of the video installation system.

These projections created a shared experience between the tables. The real-life projections frequently shifted with a stylised flash animation that showed a diagrammatical visualisation of recorded territorial occupation of café-tables. In that way the installation both questions the café as territory but also the territorial interference within the group around a table. The installation ran for two weeks in the cantina of the Oslo School of Architecture.
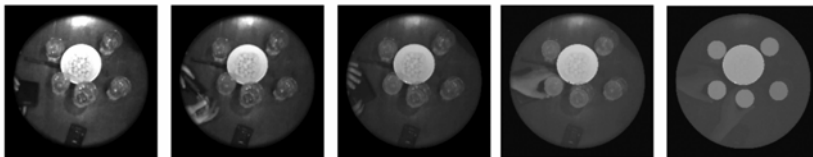
Figure 152 Video registration and visual analysis of cafe table. The tableware objects are transformed into diagrammatical elements which make it easier to see and analyse their movement.

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Figure 153 The abstraction of the tableware and its usage lead to stylised animations of territorial occupation of table tops based on real-life observations. These animations were projected back onto the table tops in the installation.

5.2.2. Intentions of response to the complexity of urban systems

Generative computing can be used strategically in creating design interventions in complex urban systems. The strategies and techniques described here are a suggestion for dynamic design strategies where the potential to host or trigger future unforeseen events and to adapt to future changes in the systems are in focus.

Intentions
The intention of the experiments presented here is to design adaptable systems which are able to absorb future unforeseen changes. The main strategy is to design undetermined, and at the same time very specific and highly articulated, geometries that create a playground for future partly unforeseen forces, the actions of contemporary and future stakeholders, and the effects of developments that we cannot predict other than on a very superficial level. The central tool for evaluation of the future performance of these designs are scenario techniques that test the systems for extreme or very different events.

Relevant Techniques
All kind of generative design, observation and scenarios. The opportunistic use of mixed techniques points to the concept of the Hybrid Process.

The techniques I describe in this thesis are partly designed to respond to complexity. Handling complexity is an inherent feature of the computer because it helps us to do very complicated calculations which we can use to monitor, simulate or generate complex systems. Responding to complexity in design demands flexible and dynamic design techniques. The whole design process needs to have a certain level of complexity to be able to produce the

merged, negotiated and composite responses needed in a design that intends to respond or intervene in a complex situation. The interwoven use of complex techniques mirrors the complex issues of urban life.

In the following, I present a case on the urban scale. The reason for choosing this scale, is that it provides a level of complexity that is particularly challenging and that would be suitable for developing and exploring digital design techniques. My background is not from urban planning. Any projects on the urban scale in which I have been involved, have all been in collaboration with people who have a background in architecture / urbanism. The work we developed together however has fitted well with my conception of urban design.

First of all, this thinking regards the city more as a result of the development of an organism constituted by a large number of operations, actions and forces over a long period of time, than the result of clear, fixed and controlled planning. These forces are partly out of control and planning therefore needs to absorb rapid changes and uncertain futures even as the planning proceeds. This is a theme which has been treated in depth, when it comes to the building scale, by Stewart Brand in his book How Buildings Learn. (Brand, 1994)

Michael Hensel and Kivi Sotamaa use a model of ecology as a means of design intervention (Hensel and Sotamaa, 2002). They problematise the contradiction between the complex dynamic relations in our modern life on the one hand and the fixed ideas of the design object (in this case the master plan) on the other.

> Today the increasing complexity of dynamic relations between human activities and the hosting milieus renders the fetishization of discrete and exclusive design objects increasingly futile. This is what happens when the consolidation of the assigned meaning or prescribed functionality of the design-object begins to delimit the interaction between subject and environment. OCEAN NORTH´s approach to design emphasises therefore the inter-relational make-up of the environment as a dynamically unfolding generative field, and suggests an organisational paradigm for design rooted in a radical shift towards a primacy of process over events, relationship over entities and of development over structure. (Hensel and Sotamaa, 2002)

The techniques and design strategies we developed were designed to create environments and systems that would be able to respond and absorb future uncertainties. They were also designed to help us to speculate on the play of forces in the urban space. The techniques should be suited to synthesizing flexible solutions on a speculative basis derived from complex and partly

fluid background information. The techniques should also be generative and inclusive. Hensel and Sotamaa continue to discuss some important questions that arise from this position. The question of control and lack of control in the design process and the following issue of open-endedness:

> To which degree can design control be suspended or relinquished? Within the ecological design paradigm the role of control must shift, from consolidating stable alignments and characteristics between constituent elements within a milieu towards temporal regulation of generative processes….
> How can relational dynamics be regulated without reinstigating an inflexible form of hard control? (Hensel and Sotamaa, 2002)

In the 2001 issue of AD on Animation there is an article where Ali Rahim interviews Bernhard Tschumi. He asks Tschumi about the influence of chance in the design process. Tschumi answers basically that chance does not play any role in his design process but it engages the result:

> Our intention is not to condition design (even with chance strategies) but rather to design conditions so as to allow for chance encounters or programmatic collisions. Their manifestations are always more or less than predicted, as architecture is inevitably subverted by some of its uses or users. (Castle, 2001)

Later Tschumi states:

> I define architecture as the encounter of space, event and movement. Hence, it is inevitably about dynamic sequences of movement unfolding within static sequences of spaces. (Castle, 2001)

I basically share the intentions of Tschumi, and in the following case these intentions have been central. Though I think *chance strategies* are beneficial as an intentional strategy for a design. I think it is not necessary to use such strategies in a design project, but I think these strategies are well suited especially when we want to design for the allowance of 'chance encounters or programmatic collisions'. An architecture that intends to design conditions for an unforeseen and changing future needs to be open-ended and ambiguous. Hensel and Sotama refer to Umberto Eco´s 'Opera Aperta' (The open work)

> …. in which he posits a notion of openness of a work (of art) yielded by its deliberate ambiguity. (Hensel and Sotamaa, 2002)

Generative design techniques are ideal tools to subvert our desire for finite design solutions and to maintain open-endedness and ambiguity. In another paper Hensel reframes these intentions:

> The hypothesis that underlies the following design-based research (referring to a series of OCEAN NORTH projects) is that the relational dynamic between object and subject, environment and inhabitants establishes a potential space in which social and cultural experience can be located (Hensel et al., 2004a).

I think we are far from really answering all the questions arising from these attempts at revolutionising design methods, but we have come a long way in suggesting some concepts and potential principles. The following is a project that intends to bring the flexibility strategies and the open-endedness of the "ecological paradigm" together with the uncontrolled and open-ended approaches of design computing. The intention is to provide for a type of architecture where the interrelation between inhabitants and environment establishes a potential event-space for the development of social and cultural activities. The result is a deliberately ambiguous architecture.

An Example : "Ambient Amplifiers"

In this example we return to the Ambient Amplifier project which we have looked at earlier in the analysis of Tøyengate.

Ambient Amplifiers (Sevaldson and Duong, 2000a) is a design and research study which aims to explore how digital modelling can contribute to the formation of generic concepts, (like programmability of built form) applied to a real-life scenario. It is also a study in the development of new digital design techniques. The project, located in a park area in the east of Oslo, treats a series of elements and sites within the area and indicates several interventions which were mostly developed to a sketch level.

Tøyen Park is a relatively wide and diverse park area with a broad range of public and cultural institutions and a varied landscape including hillsides and small wooded areas. It includes the Oslo Botanical Garden with the Botanical, Paleontological, Geological and Zoological Museums. Amongst the numerous cultural institutions in the area, the two most important are the Munch Museum and the Tøyen Cultural Centre. The park as a whole, together with the Tøyen Baths and several sports grounds, forms the most important leisure facility in the east of central Oslo (Figure 154).

Despite the rich variety offered by the park facilities, there is hardly any synergy between the main actors, and the park is not used to its full potential when compared to the Vigeland Park in the west, which is solely a sculpture park, lacking the programmatic richness of the Tøyen area. One obvious aspect is that the Tøyen Park lacks a central attraction that would create synergy and tie the different institutions together. The central area of the park is an undeveloped parking lot, a space which is also used for temporary events

The reason for the lack of intensified usage could possibly be found in the social structures of the neighbourhood surrounding the park. But it also seems to be caused by what we could call geometrical features. This includes the way the park is connected or divided from the city and what kinds of attractors are found and how they are distributed in the area.

This rather superficial analysis of the 'problems' of the Tøyen Park was used as a starting point for the project. This is quite similar to a conventional design process where a problem is defined and a solution is suggested. The difference lies in the process and the suggested solutions or rather the soft intervention in the system of the Tøyen Park. Instead of providing a solution to a problem in the traditional sense, we develop some devices that are meant to be interfaces for the tuning and adjustment of the 'system Tøyen Park'. The devices are meant to be operated by some of the main actors present in the park. This provides responsibility, the power to influence and flexibility to the system.

The design interventions in Ambient Amplifiers reinforced both the main central field of the park and the corridors that feed traffic into the park area. In the design study of the central park area, a system of point attractors, a treatment of ambient surface paths and a redesign of the vehicular transportation systems were suggested.

Short description
Ambient Amplifiers engages several concepts to create a richer and more attractive environment.

Point attractors
For the Tøyen Park it became clear that we needed to address the vacuum in the central area of the park which is currently a parking lot and an area for temporary events like circuses. We suggested a distributed number of central attractors instead of one singular attractor. The reason for this was to create a more flexible and adaptable field where synergies and co-operation between the institutions could take place. Also the field should still maintain the ability to host the existing temporary events (circuses and others) and even provide facilities for a broader range of events (e.g. concerts).

Figure 154 Map of Tøyen Park with the three categories of institutions, Art, Science and Leisure. The ethnic street Tøyengate (marked red) is treated as feeding corridor. Central parking lot area north of Munch museum.

We called these attractors 'islands'. This was inspired by the project Surrounded Islands by Christo, in which preparations involving communities, industries, environmentalists, court decisions, public debate and the ongoing debate during and after the installation are all part of the work. I have always admired Christo as an artist, but this particular project reflects the broad involvement he emphasises in his exhibitions[131], and which is especially relevant to us here. Our concept plans to have a similar effect but over a longer time span.

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[131] I have seen this at the Hennie Onstad Art Center outside Oslo in the exhibition Christo «Surrounded Islands» in 1984

Ultimately, Christo's islands also inspired the layout of our attractors. The attractors were landscape forms or places that could be developed into different variations from the beginning and which could be altered at any time

Three sets, each containing several "islands", were distributed in the field Each of the sets belongs to one of the main institutions in the park. The intention of this approach is to produce synergies between the three institutions on an organisational level but also on a spatial level simply by bringing satellites from one institution into the territory of another. The "islands" were designed in diverse "unfinished" states, from "footprint" in the landscape to pavilion. (see Figure 164) They were distributed on the site in a way that would provide for the following (see Figure 162):

- Establish spatial and organisational relations between the three main actors on the site while maintaining responsibility and ownership (Science, Art and Leisure).

- Prepare a ground for a wide range of activities to take place.

- Introduce a flexible system that could be re-inhabited according to unknown future activities, without necessarily big structural modifications. This introduces the notion of programmability to design.

- Establish a pattern of attractors that would operate as a singular attraction on a global level to bring people to the site from distant locations.

- Establish singular attractor-points in the field, with varied quality and intensity. This allows them to operate towards a wide range of interests.

Ambient surface paths
The park has already a developed system of pathways for pedestrians. However these pathways follow a layout that is designed according to a need of transportation between the central places and adjacent areas. The existing path system establishes a clear separation of functions, where walking and leisure are separated by choice of surfaces (asphalt and grass). The new surface paths introduce a soft border between walking and playing (bikes, roller blades, ballgames and others). It also provides for additional modes of walking, apart from walking for the purpose of transportation (strolling, meandering). This is achieved through the varied form and layout of the surfaces as well as their lack of functional direction.

Programmable Street

The existing street system that crosses and divides the park, was redesigned to adapt to a wide range of possible events, some of which already take place at the site (e.g. circus). Rather than reducing the traffic or leading it away from the Park, which would cause traffic problems elsewhere, was distributed over a larger area in a way that allowed it to adapt to real-time events on the site. The street system was spread over several branches which could be used to redirect the traffic to give space to some events (e.g. concert) or to feed traffic into others and provide temporal parking areas (e.g. circus). Temporarily closed branches were used for parking or leisure. The system is dependent on a delicate treatment of the surfaces and its materials and redirection systems.

Design process

The complexity and open-endedness of the design intentions required a design process that was able to include and digest a large amount of information and which was able to deal with complexity and adaptability. A period of research was necessary, not primarily to create a knowledge base from which it would be possible to determine logical conclusions (cause - effect or deductive hypothesis based thinking), but rather to establish a shared, interdisciplinary, intuition of the area. The main tool for this was an intranet website where all information was stored (Sevaldson and Duong, 2000b). This ensured a common information platform for both participants and made a large amount of information accessible (Figure 155). The intranet was also used as a design tool where all kinds of process-based experiments were stored and shared. Digital and physical modelling as analytic tools was used from the beginning. This shows that there is no sharp division between analysis and design but an ongoing interplay between them.

The partly intuitive process mirrored the complexity of the design task. Though many aspects in this project were treated in a superficial way, the project is interesting because it brings together several aspects of digital design:

- The handling of complex information with graphical tools.
- A smooth transition from diagrammatic analysis to generative design.
- Bringing together site-data and information with generative material.
- Maintaining site-related information through both analytical and generative phases, where the site information constantly is injected throughout the process on many levels.
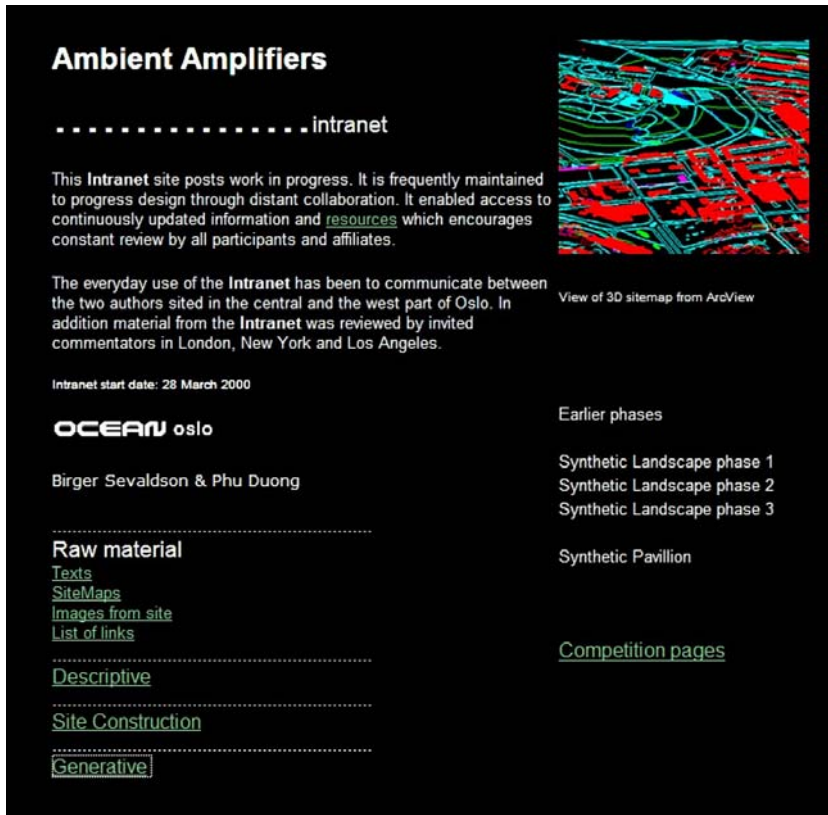
Figure 155 Screen dump of the intranet for Ambient Amplifiers.
(http://www.aho.no/staff/bs/ambient_amplifiers)

The project provided us with a 'space' for collaborative design that was interactive and that contributed to the understanding of these processes as a composite of information handling, machine emergence and human intuition. These aspects led later to the development of the hybrid process.

The source material for Ambient Amplifiers originates from the preceding project, Synthetic Landscape. There is no sharp distinction between the two projects, but Ambient Amplifiers develops in a slightly different though related direction than Synthetic Landscape[132]. In Synthetic Landscape, the focus was on the development of strategies for complex dynamic programming ('Channelling Systems').

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[132] Here synthetic refers to an imagined, machine generated environment, but also the synthesis of a variety of disciplinary visions.

Ambient Amplifiers developed along lines where we investigated the construction of dynamic design spaces and the rehearsal of 'chance strategies' both in the process and in the result. To describe the process we need to reach back into the last phases of Synthetic Landscape where the source material for Ambient Amplifiers was actually produced:

A particle animation was applied as initial generative diagram for the three interventions in the central field (Figure 159). The generative diagram, in this case, was a particle animation fed by both generic information and contextual forces. (The particle animation was produced under a series of preceding design studies in the same area, "Synthetic Landscape I-IV" (OCEAN et al., 1998)).
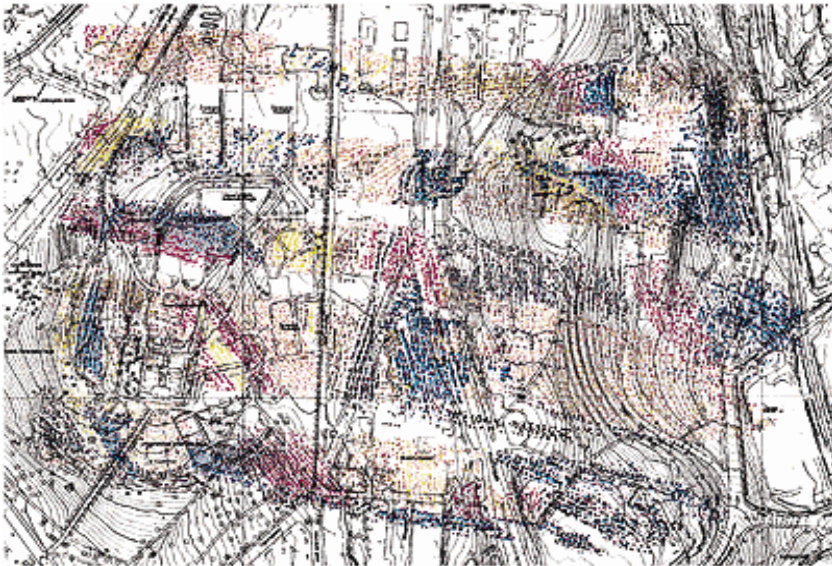
Figure 156 : Colour graft mapped onto a map of the Tøyen Park.

Particles in animation software are used to render very complex geometries like smoke, splashing water, hair and similar phenomena. Since their input variables (like density, forces, colours and material appearance) can be tuned freely their use is not limited to simulating or illustrating natural phenomena but they can be used to produce abstract spatial time-based geometries as well. The fact that the particle animation algorithms operate with forces (e.g. magnets, gravitation, draft, friction and density) makes them very well suited to developing spatial dynamic constructs that feed on either specifically coded input variables or generative spatial systems. The particles from

"Synthetic Landscape III" where produced from both generic input and site-specific geometries. The generic information was a colour-graft (a hand drawing by Johan Bettum) made specially to serve as colour graft for "Synthetic Landscape II"(Figure 156).

The colour-graft was split into six colour channels (Photoshop) which were used as displacement information to deform surfaces. Peaks depict high colour intensity while valleys correspond to low colour intensity. These surfaces where scaled and wrapped to a topographical model of the site (Figure 157). This produces surfaces that contain both the generative information and site-specific (topographic) information.

To process the data further, to develop the site-relative aspects and produce a time-based generative material (dynamic generative diagram), the data was processed in the following way:

- **Data reduction:** Intersection curves between the topographical model and the information surfaces where generated to produce a common reduced information set (Figure 158 bottom).

- **Data expansion:** The intersection curves were used as trajectories for animated particle generators, which introduces time as an element in the diagram (Figure 158 top).
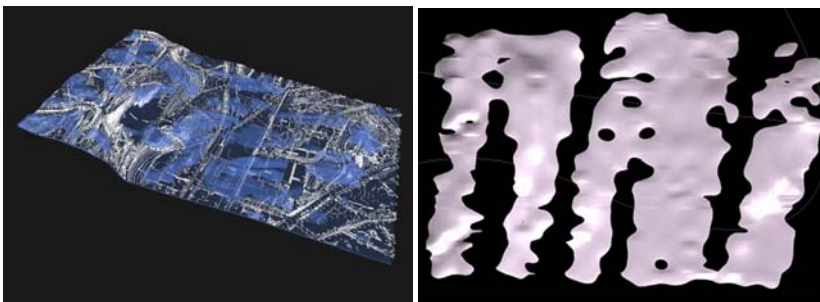
Figure 157 To the left: Displacement surface mapped to topographical site model. To the right: Contours of intersection lines. Visible only the part of the displacement surface that is above the topographical surface.

Force instrumentalisation: The particles were used to render qualitative spatial relations between some of the "static" elements on the site. (Scientific Museums, Botanical Garden, Munch Museum, Tøyen Baths and Finnmarksgate, as the main traffic direction through the site) To do this, these elements were equipped with magnetic forces that influenced the particle flow (Figure 159).
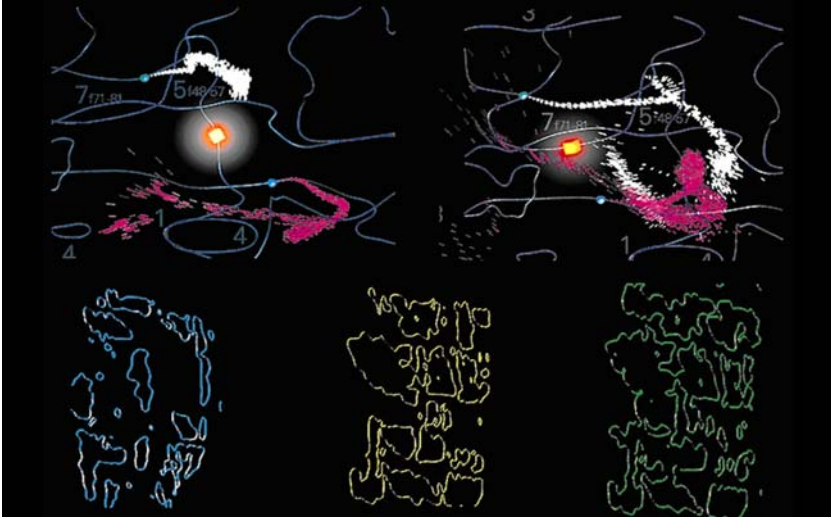
Figure 158 Bottom: Intersection lines generated from the intersection between the topographic model and the displacement surfaces generated from the colour graft. Top: Animated cursor, some with particle generators following the intersection lines.
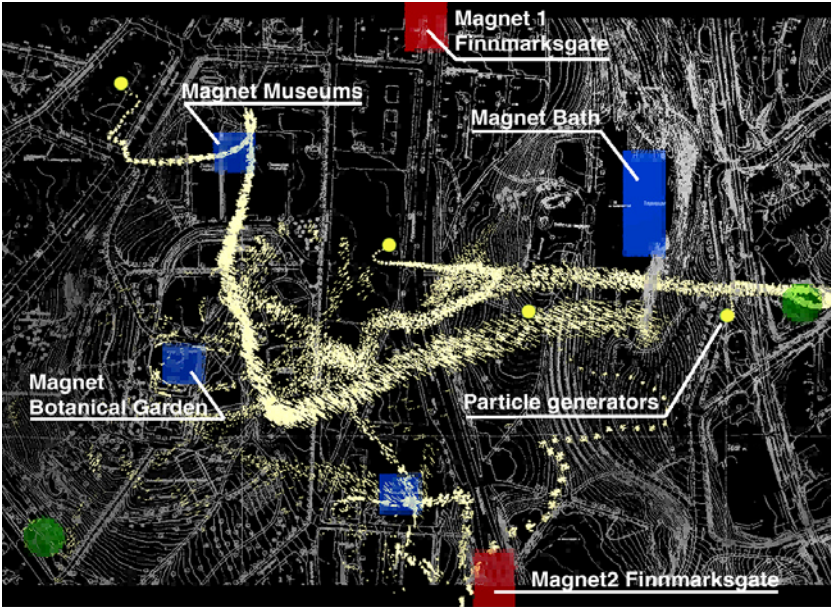

Figure 159 Map of particle generator and force set-up. Trajectories (intersection lines) not visible.

This set-up produced a series of six different animations intended as generative diagrams for an intricate urban analysis based on six channelling systems, (Bettum and Hensel, 2000). The particles in the diagrams produce spatial configurations influenced by the grafted information (colour graft) and site information (topographical model and "static" elements) and the speculative development over time.
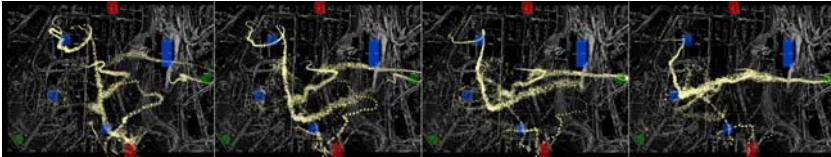
Figure 160 Series of frames from the particle animation used to inform the layout of the site.

This was how far Synthetic Landscape reached before the project was terminated.[133] Ambient Amplifiers sought to pick up on the results of Synthetic Landscape and develop implementation strategies of the rather abstract results from Synthetic Landscape. Ambient Amplifiers can be seen as one example of an applied solution to some of the concepts from Synthetic Landscape, although one could also imagine developments along other lines.

Although Ambient Amplifiers was conducted as the continuation of Synthetic Landscape, it established its own agenda. Besides the intentions already mentioned, there was a pressing need to investigate the implementation of the dynamic diagram further in a more narrowly framed and specific case.

The layout of the "islands" was directly informed by a series of diagrams derived from the particle animations. The layout and placement of the "islands" needed to be defined in a field condition rather than in the granulated particle flows that was the underlay. The selected still frames were therefore blurred to produce continuous gradients and contrast enhanced to establish slightly more clear borders (Figure 161). This translated the density formations of the particles into intensity maps. These image files were fed back into the 3D-model and used as underlay for the distribution of "islands" and the ambient-surface paths.

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[133] A subsequent attempt by Johan Bettum and Michael Hensel developed a strategic framework and set of rules for the use of 'Channelling Systems' as a design method. (Bettum and Hensel, 2000)
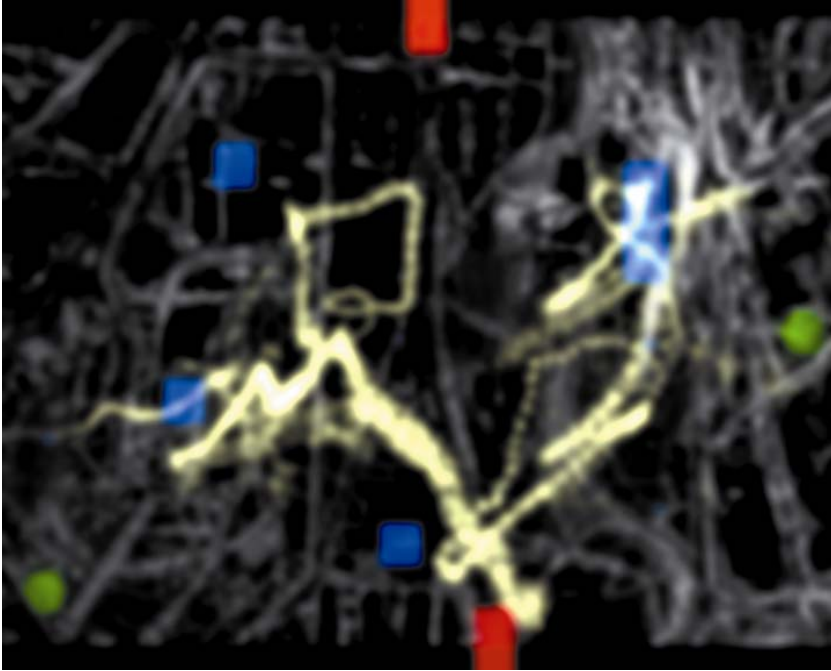
Figure 161   Selected frame used for the distribution of "Islands" The image is blurred to render fields of intensities more clearly.

This informed the placement of the "islands"[134] in positions which would hardly have been chosen if the design had been done in a conventional way. Some "islands" landed in the middle of existing streets, some right on top of the fence which divides the botanical garden from the rest of the park (Figure 162). The placements were coincidental (out of control) but closely related to the anatomy of the site. This is the unique quality which is specific to the described computer-based techniques.

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[134] The invention of the islands as attractor devices was inspired by Christo's project "Surrounded Islands". Christo emphasized the importance of the engagement of public society, political decision making, and the involvement of a big and complex production process. This part of the project together with the ongoing debate during and after the installation was regarded as central effects of the installation.

Figure 162 Distribution of the three sets of "Islands". From the left: Science, Leisure and Art. Botanical Garden is seen to the left in the images, the Munch Museum to the lower middle, and the Tøyen Bath and park to the right.

The uncomposed landing of the islands provoked rethinking of the role of the islands and triggered a search for original solutions. When the generative diagram is implemented within site-specific design intentions it puts the designer immediately into a position of negotiation. Should the indicated positioning be rejected or do they indicate a potentially useful solution? In all cases where the position is questionable, it either results in rejection or it triggers concepts with larger implications. In most cases the problematic fits are potentially the most useful because they challenge the designer's schemata. In both the cases mentioned above, where an "island" coincided with the fence and the street, its placement was negotiated in order to accommodate the existing situation and potential future program instead of being rejected. The existing street was modulated to bend around the "island", which triggered the invention of a dynamic programmable street-system. In the case of the fence, the "islands" took on the role of a threshold moderator, contributing to solving the problem of the fence which acts as a territorial obstacle for the site. This triggered the concept of the programmable fence which could be adapted to produce a number of varied access and closure states. (Figure 163)

Figure 163 The programmable street. Four scenarios for different activities at the site. Top left: rush-hour scenario guiding the traffic quickly through the area, providing extra capacity. Top right: tourist scenario, creating good access and parking capacity for the museum visits. Lower left: circus scenario, freeing space for the circus and providing access as well as parking. Lower right: concert scenario, creating an area for the outdoor event, using one of the islands as basis for stage facility and restricting access to botanical garden.
Red: street, Blue: Parking, light blue: pedestrians and sports, white: fence. Dark Blue: ambient paths. Green: special events.
The red street shows clearly how the system adapts to the different situations together with the variation in parking, or are converted into pedestrian or playground surfaces. The fence to the botanical garden responds to the different situations by adjustments to the degree of openness.

The "islands" were designed according to a flexible concept, which was based on four different states of "unfinishedness". This helped to negotiate the positions suggested by the underlay. In some cases the "islands" embody themselves just as a subtle modulation of the surface or a shift of surface materials, creating an area suited for picnics, sunbathing or similar activities ("Footprint"). In other incidents they provide platforms ("Foundation") and frameworks ("Frame") for additional activities and services. Only in a few cases the "Islands" are fully developed into pavilions ("Core"). One sample "island" was developed to demonstrate the principles (Figure 164). The underlay derived from the generative diagram indicated a large number of

"islands", more than necessarily needed, which also contributed to the negotiability of the design template. The underlays for the three sets of "islands" where chosen from three different frames in the same particle animation, which provided an inherent relation between the three sets.
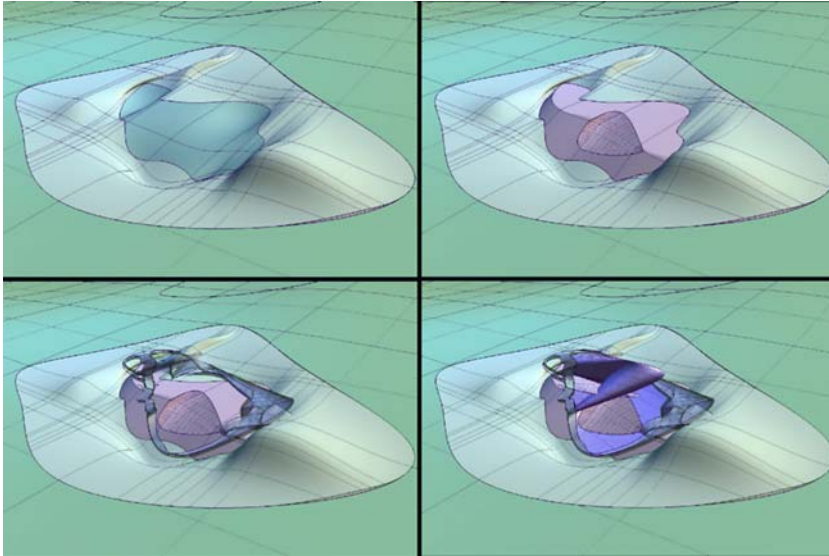
Figure 164 The "Islands" Four stages of "unfinishedness". Top left: footprint. The footprint is a articulation of the park surface with the additional use of surfaces of different hardness. Can be used for pick nicks, skate boarding playing and other activities. Top right: foundation. The foundation creates a horizontal surface that gives additional possibilities for bigger pick nicks, fire places, the exhibition of sculptures etc. Lower left: The frame. The frame adds additional functionality to the foundation. It could be used for infrastructure like electricity and it could be used as structure for a temporal stage. Clad with a textile membrane it can be converted to a temporal shelter. Lower right: The core. The core is a complete pavilion that could be used for exhibitions, seminars organisation work in the neighbourhood and entertainment events.

Since one of the most important aspects of the "islands" is to operate as devices for synergy between the three institutions, each institution manages one set of "islands". In each set only one or two are fully developed. The chosen sets for each category, were the ones which produced the most intimate connection to the two other sets and their institutions (Art has an island inside the baths area and a leisure island occupies a site inside the Botanical Garden.)

The "Ambient Amplifier" project employs a series of additional techniques to the one described above. In one of the streets that leads into the park (Tøyengate) a particle animation that feeds exclusively on contextual forces was used to create the generative material. It was later processed with an advanced skeleton technique, which in turn monitored a surface that was used as "scaffold" for the final design. This technique, developed by Phu Duong, introduces hierarchically ordered interdependent systems to the generative diagram (earlier discussed in part 4). On the other extreme, the Pavilions for the "islands" were generated from generative material that was produced through a deformation of the landscape surface driven by skeletons, where the skeleton movement was totally non-contextual. The movement was "designed" manually; an example of the intuitive trial and error approach, which brings design intuition "back stage" and operates directly on the virtual engines that produce form. This hands-on technique is highly efficient and has potential for further exploration.

This project may be seen in the light of comments by Malcolm McCullough. On generative systems he says:

> …there are dynamic representations where not having control over lower-level operations yields a higher sense of control over a complete process. One can work at the level of derivatives, for example, controlling velocity rather than position. By altering the settings of a dynamic system….   ….one can improvise within the context of a simulation. (McCullough, 1996)
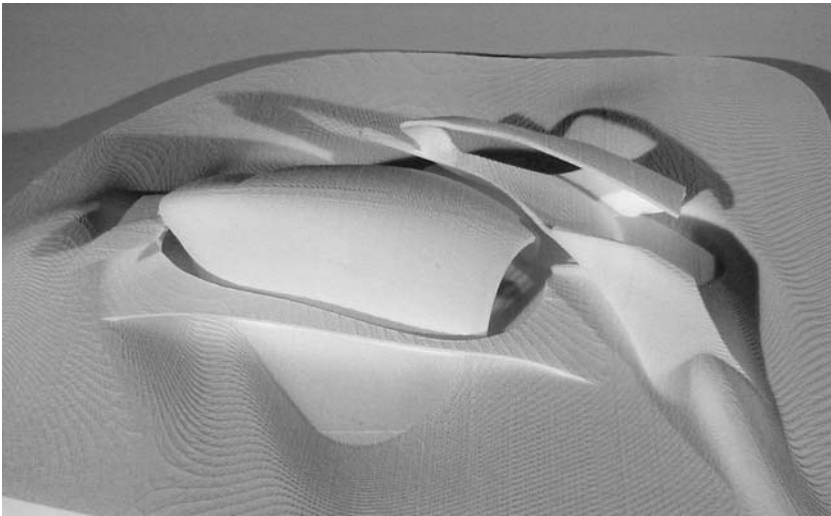
*Figure 165 Rapid Prototyping model of a sample" island".*

We did not manage to implement all the parameters and forces that we initially intended to include in the design space. This revealed a schism in the design process: on one hand we intended to investigate the complex site as deep as possible and to implement as much as possible of the collected information into the design space, on the other hand we work with generative techniques, with the intention of planning for unforeseen activities that might take place on the site in the future. This intention contradicts the implementation of parameters from the current state of the site. The project is based on a current situation but needs to have the potential for future unforeseen development. The current parameters and forces needed to be balanced and modified by other elements and forces that are of a more generative and open-ended nature. One could imagine many strategies to achieve this balance. In this project this problem was solved by keeping the injected parameters on a superficial level. The particle animation was fed by forces symbolising real forces on the site (the big attractors, social forces and infrastructural features of the site). But the particle animation also worked as an 'alienation device'. It diffused the forces in a generative animation and it was in the end not clear how these forces actually influenced the site. We speculated that they were somehow merged in the generative material though they were no longer directly visible. In a way this approach is feasible. One could imagine again the same techniques performed in a less extreme way, where the balance between the existing forces and the emergent material are fine tuned. What the animation brought forward, was the value of maintaining a general sense of the complexity in the field, but this is not to be confused with a speculation of how the forces might unfold. In addition it created a diagrammatic expression of the complexity derived from the forces.

The preconditioned dynamic diagram
The particle animation for Ambient Amplifiers was used in a similar way to the original colour graft for Synthetic Landscape. But while the original colour graft was totally abstract and free of any representational information, the particle animation was loaded with information from the site. The topography of the site as well as many of the imagined forces on the site were used as important elements in the generative diagram. It is an 'un-neutral' and 'un-alien' and preconditioned type of generative diagram, similar to the one used for the World Center of Human Concerns design project. The preconditioned generative diagram that includes some already known aspects and that initiates a generative process from this basis has an advantage. It creates structures within a given frame and influenced by given parameters. Though it is still a 'wild' output it is caged within a mainframe that implies a pre-rationalisation and systematisation of the anticipation for the output. This induces a larger degree or range of design control before and after the generative processing. It increases the designer's control while maintaining the potential in the emergent process. It also makes the post rationalisation processes and the development towards finalisation more

fluent and smooth. Playing the influences before and after the emergent processing provides a rich selection of means by which we can monitor, adjust and fine-tune the generative process. The ultimate pre-controlled emergent process is the parametric design process. The suggested approach here creates a space for operation between the hard-core parametric design process and the abstract emergent process based on generic and unrelated source material.

We need to select certain instances form the rich generated output. The selection is based on a subjective forecast of the potential of the material to be developed into a design. Not all aspects of this act of selection are possible to describe or rationalise. It is a type of craft, and partly based on tacit knowledge or 'having an eye' for which instances that are most interesting, provocative, challenging and ground breaking for the further development of the process. I think there is considerable potential in the further investigation of the preconditioned generative techniques. The real potential of these techniques is not found in an extreme alienation in the search of the 'synthetic wildness' but in the tuning and balancing of 'taming devices' (real-life parameters, topological pre-organisation, activity simulations) and the generative power in the dynamic diagram.
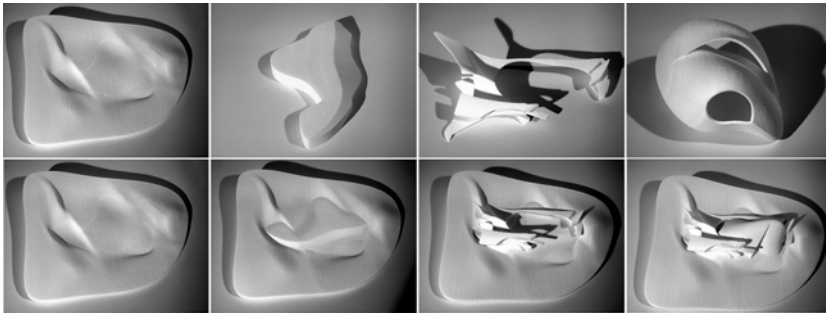
Figure 166   The complete series of study models for the one developed pavilion for Ambient Amplifiers. Top row shows the four building elements that can be varied, the footprint, the foundation, the frame and the core. Lower row shows four stages of 'unfinishedness' where the elements are added onto each other.

The chosen example pavilion was developed further to a stage where a normal design process including modifications of the main design, material realization and detailing would be the next step. Materials were concrete for the foundation, welded steel grid for the frame and composite material for the core. The pavilion was developed in a 3D model (Figure 167) and a section draft (Figure 168).

This stage of finishing the project was chosen because I wanted to document the path towards realization of a building sample. It was then not necessary to develop the project further.
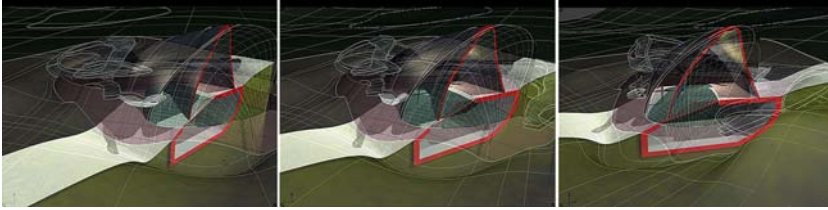
Figure 167 Three-dimensional section model of the pavilion showing landscape and invisible part of model in wire frame.
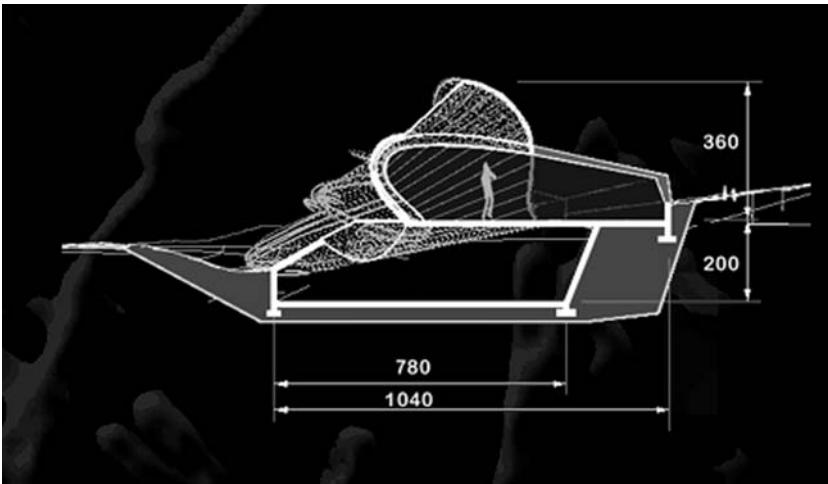
Figure 168 Section draft of the pavilion.

5.3. THE HYBRID PROCESS

I use the term *hybrid process* for the deliberate mixing and combination of a range of different processes to achieve a synergy and surplus in a design process. It is an overreaching strategy to create richer, more inclusive and more complex design processes which have the capacity to create complex responses to complex situations.

The composite process: the putting together of two or more elements to generate a new one.

The parallel processes: different techniques and media are used in parallel to achieve a deeper understanding of the process (e.g. VORB).

Sequential techniques: the shifting of techniques. Involves recoding and translation and often results in leaps in the design process.

Networking of processes: a process where several techniques, merged, parallel or sequenced are organised in a broader framework. A networked process results in a wide range of outputs, (e.g. Chamberworks).

The hybrid process: a global strategy that consciously seeks to take advantage from the connecting of multiple processes, techniques and people, be it the merging of processes, sequencing of processes, networking of processes or interdisciplinary co-operation.

The introduction of digital design tools into the design process has not really removed any of the more traditional ways of working. Exceptions are technical drafting, which is now almost entirely done on the computer. But marker and pen sketches, cardboard and foam or clay models have not disappeared. At the same time computer-use has expanded in many directions since the beginning. I claim that this is a generic trend in the development of the design process. The use of diverse techniques is already a reality in our everyday life as practitioners. The design process has expanded and we see today a richer and more layered process where we move between and combine media in an ever more complex way. But very little is said about this phenomenon of expansion. At least I have not found any sources that particularly address this issue.

The Hybrid process is a process in which the many digital and traditional techniques and design strategies melt together. The Hybrid process of today differs very much from the design process of pre-digital times. While design techniques were fairly stable before the computer, they have become increasingly fluid. New techniques and combinations of techniques are invented constantly. The designers of the digital age move between and combine the techniques in a very natural way.

 There are at least four central issues:
- A richer more complex and eventually more creative design process.
- The shifting between and merging of different techniques, modes and participants is in itself is a driving force in the process.
- The expansion of professional techniques opens doors for multidisciplinary co-operation.

- The renewing of the emergent design process with the ongoing invention and development and layering of new design techniques over time.

5.3.1. Hybridization strategies

We have until now discussed many different techniques and even in some cases the relations between them and the staging of the techniques. This is how design techniques are normally discussed. A step further would be to investigate and develop the issues that appear between the techniques in their merging and sequencing. Synergies may be found in driving the process forward, in the interdisciplinary aspects, and in the shift from rigid design methods to the more explorative and emergent design techniques that are required when exploiting the multiple uses of diverse tools and techniques. When a process is regarded on this level, I call it a hybrid process. The Hybrid Process is a process of hybridization strategies that include attempting to create synergies between the differences in the process.

The Hybrid Process is also an emergent and explorative process, a process of shared interest and loosening of control, where we seek the synergies that might appear from moving the process between different representations, models, techniques, professionals and ideologies. Hybridization strategies involve the weaving of relational networks between a branched process that operates simultaneously and sequentially with the merging of different techniques strategies and ideas.

Amongst the suggested hybrid strategies used in the presented projects we find the following concepts:

Composite processes

In Part 4, I mentioned the difficulties of categorisation, because of the fact that the discrete techniques most often appear together in a mixture. Pattern recognition and video based analysis is an inherent part of any animation technique. Parametric design and animations or simulations melt together. Direct modelling is found in animation techniques e.g. in the manipulation of skeletons with inverse kinematics or in the manipulation of time-graphs. Another example is the use of drawing pads or mouse to paint e.g. a landscape with objects like trees, or the earlier described use of paint tools to manipulate surfaces. When the techniques integrate and constitute a new one this is a composite process.

Parallel processes

Parallel processes are processes where the same or similar processes are done with several media. The timing here is less important but the point is the similarity of a process explored in different media. This could be done by one person in sequences but its most natural form is a collaboration between different working groups using different media. The benefit of a parallel process is that the changing and comparing of different media potentially provides material for slightly different interpretations. (See Figure 69)

Sequential processes

When switching between different processes where one process and its tools picks up where the other ends, we achieve development leaps that move the process forward or in a changed direction. The conscious use of shifting between processes results in an increased output. Sequential processes also include the passing on of work from one person to the other as we practiced in OCEAN NORTH or in interdisciplinary cooperation (e.g. in the World Center for Human Concerns and AGORA). The effect of sequential work is the resulting influence between the stages when shifting from one to another that creates a critical distance to the subject and a reinterpretation of the work. In many cases it has an accelerating effect on the development of the project.

Networking of processes

Networking of process implies the creation of a setting for a design process that consists of several interlinked processes and techniques in a sort of "process-soup" that creates a critical mass of output material. This provides for a richness and diversity that fuels the process. In this case more is better than less. A certain level of richness in the produced material is beneficial regardless of the specifics of the material produced. It equals a sort of material and visual parallel to brain-storming. The interpretations from many material and visual expressions rather than one or a few contributes to a more creative process. The networking of these processes means to connect, relate and bring together these different techniques and processes. Amongst networking strategies we find parallel modelling, sequential modelling (passing on material between individuals), group work strategies and co-operative networking.

Co-operation and interdisciplinarity

The natural expression of networking processes is co-operation and interdisciplinarity. But co-operation is often understood to mean that different individuals contribute to a whole and reach a consensus. The key for fruitful co-operation is to maintain a tolerance for the lack of clear consensus. Tolerance towards a differentiated, branching and heterogenic process is a precondition for a successful networking of processes that

produces the richness of the output mentioned above. Co-operation may sometimes mean working apart and with less connection and mutual control. This means that certain parts of a process are done separately and responsibilities are given to parts of a collaborating group. Such separation ensures the development of the process in distinctly diverse directions. The merging and negotiation of the processes in subsequent phases is equally beneficial in the search for new solutions. The phasing of the process must be dynamic and go in loops so that feedback mechanisms are secured (which is often not the case in traditional designer-engineering relationships.) Examples of such co-operations are found in almost all projects presented here. They are notably obvious in a_drift, Chamberworks, World Center for Human Concerns and Agora.

A Case: AGORA

As already mentioned, the categories seldom appear alone in a process. In most cases we find combinations and mixtures of the many techniques. This case has been chosen for the particularly hybrid nature of the process and because this is so clearly reflected in its results.

The AGORA project was a collaborative effort lead by myself and the composer Natasha Barrett. AGORA resulted in two events, one sound and space installation at the Oslo Central Station, called AGORA: *boundary conditions,* and an installation / music theatre / performance at the Black Box Theatre in Oslo (AGORA).

The intention in AGORA was to investigate the relations between various types of physical and auditive spatial representations and to create a unique spatial and auditive experience. Also the gap between digital and analogue representation was bridged, especially in the design process but also during performance.

AGORA:
Concept and Project management: Natasha Barrett and Birger Sevaldson
Composition and programming: Natasha Barrett
Installation: Birger Sevaldson, with OCEAN NORTH: Tuuli Sotamaa,
Michael Hensel
Programming and electronics: Øyvind Hammer
Proiect-team: Are Nielsen, Markus Høy-Pedersen, Hanne Marte
Holmøy, Ambjørn Viking, Sylvia LeSoil, Heidi Leren, Dan Sevaldson,
Svein Berge.
Project management, *Rom for kunst*: Mesén as
Rigging: All Production, Håkon Klemetsen

AGORA : *boundary conditions* is supported by:
Fond for Lyd og Bilde, Norsk Kulturråd, Celexa, NoTAM and Abry
Design

AGORA (Black Box)
Composition: Natasja Barrett
Installation: Birger Sevaldson
with OCEAN NORTH
Soprano: Kristin Norderval
Production: Oslo opera net, Ketil Akerø
Direction assistant: Janne Wettre
Choreography assistant: Jane Hveding
Light: Kurt Hermansen

Reading of old nordic texts: Magnus Rindal, Director of Norsk institutt
for forsking om oppvekst, velferd og aldring (NOVA)
Reading of English texts: Michael Benskin, Institutt for britiske og
amerikanske studier, UIO.
Reading of Norwegian and English texts: Truls Tveito
Programming and electronics: Natasha Barrett and Øyvind Hammer
Rigging: All Productions, Håkon Klemtsen
Design, workshop, and rigging: OCEAN NORTH: Tuuli Sotamaa og
Michael Hensel.
Markus Høy-Pedersen, Are Nielsen, Hanne Marte Holmøy, Sylvia
LeSoil, Heidi Leren, Dan Sevaldson, Svein Berge. Egill Reykdal, Beeke
Bartelt, Marianne Askheim, Ruben Sevaldson, Axel Haugen

AGORA is supported by:
Norsk kulturfond
Fond for utøvende kunstnere

With modern audio techniques (ambisonics) it is possible to produce a three-dimensional sound space where sound is located accurately in space. The result is best understood as a parallel to a hologram. Together with the physical elements of the installation it is possible to create a new space where sound and architecture reflect each other. This is the framework for the concept of AGORA.

AGORA was set up on two occasions, first at the Oslo Central Station and later at the Black Box Theatre. The physical installation was recycled and all elements were reused at the Black Box Theatre. The sound though was different. For the Central Station there was a recorded soundtrack with some physical sound elements that were triggered by an infrared trigger. At Black Box there was a 60 minute composition with taped sound, real time processed sound a soprano singer whose voice was also processed real time and the physical sound elements (membranes and cylinder bells).

Figure 169 Overview of the installation at the Oslo Central Station main hall. The installation was conceived as a parasite resting on a pedestrian bridge that connects two first floor areas with café shops and boutiques. The ambisonic sound system was located on the rightmost half of the bridge, the stereophonic sound system was located under the bridge.

Figure 170 The installation engages with public and commercial spaces and sound-scapes.

The installation was built from 150 meters of aluminium tube creating trajectories through the space and five semitransparent textile surfaces. In addition there where physical elements that produced sound: five cylinder balls with electronic hammers and long aluminium rods and eight plastic membranes which where driven by parts of old hard-disks. Everything was controlled from a central computer.

The audio systems varied in the two set ups. In *Boundary Conditions* at Oslo Central Station, there was an ambisonic cube with eight speakers and a stereophonic system with four speakers. In the Black Box performance there was an ambisonic hexagon with six speakers and additional eight speakers in a stereophonic system.

In Boundary Conditions the installation ran full time for ten days. There was also an infrared trigger which responded to the movement of the audience and slightly changed the automated computer program. Travellers at the Central Station could experience the installation in different ways. While walking past through the main entrance hall one would experience the installation from below and mainly the stereophonic sound from underneath the bridge. While waiting for a train many passengers found the time to walk upstairs and explore the space on the bridge including the triggered electronic hammers and the ambisonic sound system. These different modes of how the installation engaged with the audience created a relation to public space that did not intend to impose or even expect particular behaviour from the audience.

At the Black Box Theatre, there was a one hour performance which included a musical composition of 60 minutes duration with taped sound, real time sound processing, physical sound actuators (membranes and hammers), a computer monitored lighting system and a life performer, the soprano singer Kristin Norderval. The performer operated more as a spatial element equal to the other spatial elements in the installation in the spirit of Oscar Schlemmer's theatre. The installation was built from the same elements as the installation at the Central Station, but they were reassembled in a different way. The audience was placed in the middle facing one direction, surrounded by the installation. This created a performance space that had directionality but which at the same time was distributed all around the audience.

The performer moved around and engaged with all parts of the installation, sometimes out of sight and in darkness and sometimes fully visible in front, on to the sides or behind the audience. Her voice was recorded with a microphone and run through real-time processing filters. Also it blended with recordings of other voices reading fragments from Norwegian texts (Ibsen, Obstfelder, Wergeland), English texts (Poe, Lewis Carroll, Wordsworth), old

English texts, fragments from «The Exeter Book» and other texts from the ninth century, and old Norwegian texts from the "Elder Edda". The sources emphasise the general and timeless dimension in the material through the sound composition.

The installation was lit by a computerised lighting system that received steering signals from one of the two sound computers. The audience was surrounded by a dynamic space that constantly changed with the lighting and the spatialisation of the sound space. Also the mechanical actions of the electronic hammers caused the installation to vibrate. The soprano singer moved around constantly altering the point of focus and together with the focal points created by the installation and lighting and the sound-scape, the relation and reading of the space was constantly modified.
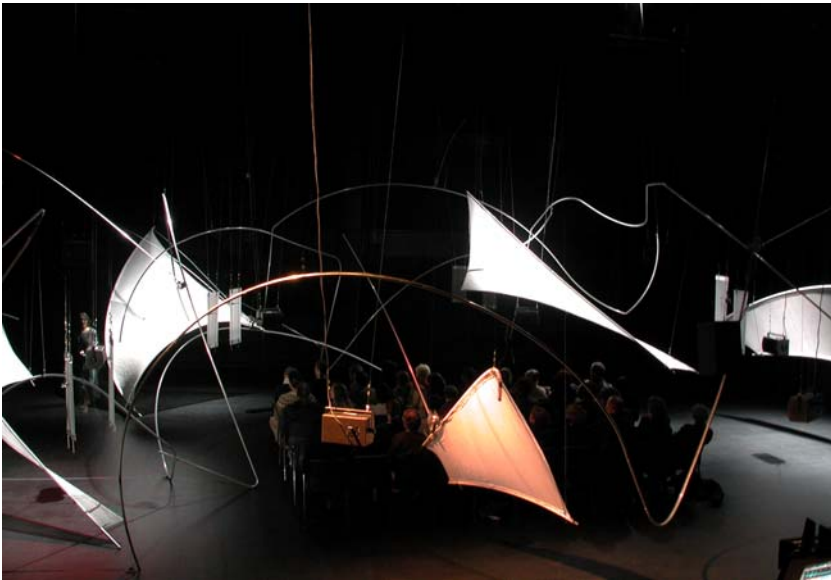
Figure 171 The installation surrounded the audience completely, almost like an inversed amphitheatre.
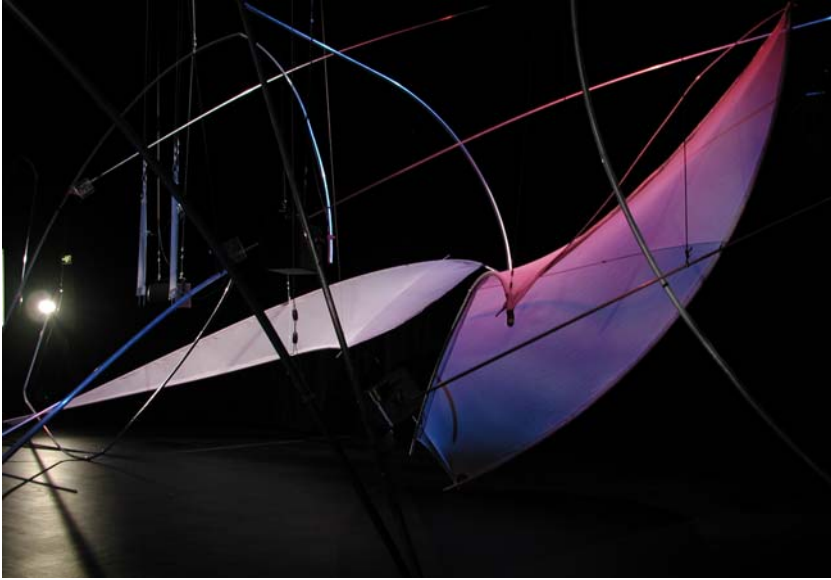
Figure 172 Textile surfaces and tubular structure. The textiles were of the "Shark Tooth" type which gives a variation of transparency and opacity effects when lit.
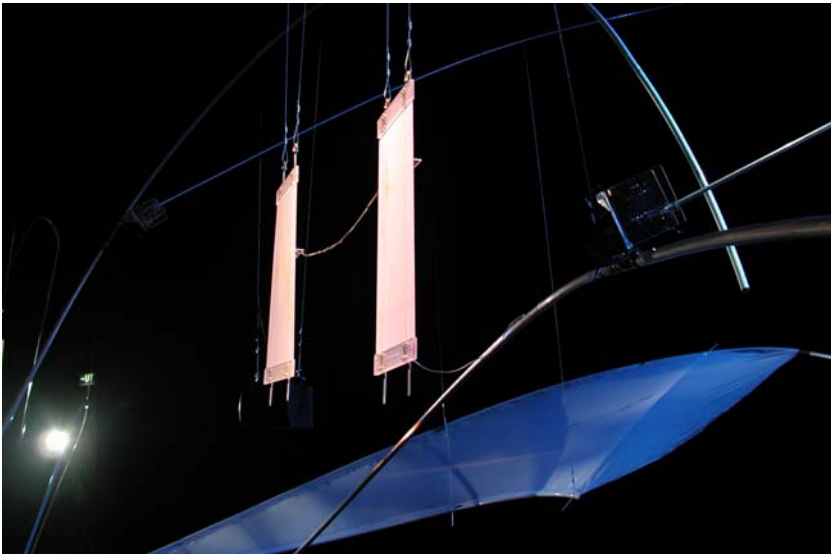
Figure 173 Textile surfaces (blue) and two plastic membranes (white). Two electronic hammers with connected aluminum rods are visible to the left and the right. They are mounted to the tubular aluminum structure.

5.3.2. The hybrid process and its elements.

In most cases, different intentions and techniques are mixed and appear side by side.
I have chosen to discuss AGORA because the design of the physical space demonstrates several of the digital techniques described above and combines them with physical modelling techniques across representational and professional boundaries. This illustrates the hybrid process.

The hybrid nature of the process is also reflected in how the musical composition was created, containing electronic synthetic sounds, recordings of real-life sounds including the voice of the real-time performer and others. In this description, I will limit myself to discuss the design of the physical installation and the *techniques* that were involved.

Parallel modelling
In this project, a group of colleagues and students were engaged in a physical modelling process that ran parallel to the initial digital modelling studies[135]. The physical and digital parallel modelling phase took place at a very early stage of the process, and was the main tool to create and manifest the concepts of the project. During this phase, the team was expanded with several of the OCEAN NORTH colleagues and some students from AHO. This phase was not productive in the sense that it actually produced results that were used later in the process, but it helped to eliminate a number of possibilities and to focus the project. It contributed to consolidating the design team which ended up consisting of only Natasha Barrett and myself. But in periods the influence of other partners was very apparent, for example during the programming of the agents' software for the source material by Øyvind Hammer and the lighting design in the final performance at the Black Box theatre in Oslo by Knut Hermansen.

Strategies to relate generative processes to site (relational strategies)
Relational strategies deal with the weighting of the generative and the existing conditions. The degree of influence of the site conditions can be altered. It can be dealt with within the negotiation phase only, which implies that there is no initial relation between the site and the emergent material. The virtual material operates as an alien element that lands on the site with no initial relations. As mentioned earlier, different strategies include elements and information from the site already from the beginning. In this case the source material for the spatialisation is informed and planned around a generic setup of the sound system and the audience.

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[135] Unfortunately the documentation, video footage and digital images from the physical modelling process were lost in a data crash.

Examples which we have considered earlier in this thesis are the World Center for Human Concerns, and especially Ambient Amplifiers. This is not to be confused with parametric design, but it is a hybrid process where different layers of information are treated in several phases. The site is constantly taken into account through the process from the beginning. In the case of AGORA, this was the case even if the site was altered twice during the project. But in this case the important issue was the structuring of the gallery space where the installation was built. The pre-structuring of a generic performance set up was introduced already in the construction and programming of the software that generated the source material (Figure 174).

Simulation
To create a common database, special software was programmed (Øyvind Hammer) which simulates the behaviour of several pairs of virtual persons (agents) who seek towards certain places and simultaneously avoid colliding with each other or the physical parts of the space. The agents do not represent the movement of real people. They generate the potential movement of the space, the sound and the actor.

It was a natural step to use a common database for both sound spatialisation and the spatial organisation of the physical installation. This source information was produced in a simulation specially programmed by Øyvind Hammer for the project. A flocking bird algorithm was modified to simulate the movement of pairs of agents through the imagined space of the installation. They were programmed to be attracted to each other and to certain attraction points and to avoid the fixed elements of the installation space, the audience space in the middle and the loud speakers (Figure 174). The image shows the trajectories of the agents after a completed run. The different pairs of agents are coded in different colours. The software had two input parameters that could be varied to produce a large variety of outputs (Figure 175).
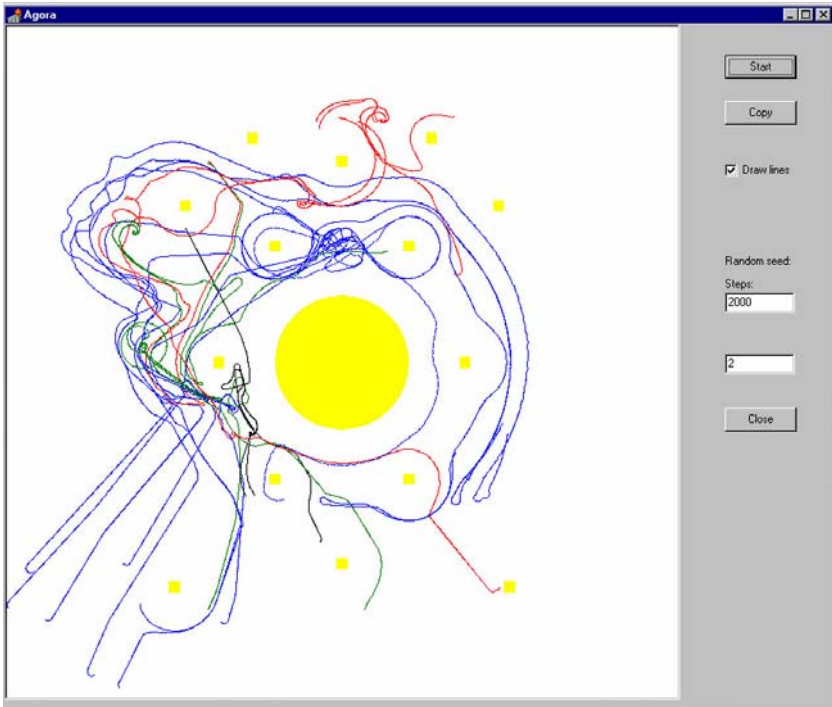
Figure 174 Screen grab of the special software written by Øyvind Hammer for the generation of trajectories that could inform the physical and auditive spaces. The simulation shows the trajectories drawn by pairs of "agents" in one instance of several thousand possible runs. Yellow elements indicate speaker systems and in the middle audience space.
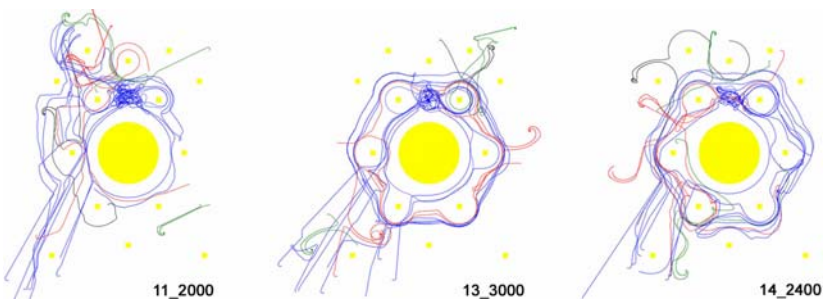
Figure 175 Four of many possible emergent configurations of the space produced by the paired agents.

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Spatial organisers and design template

The trajectories from the simulation were translated into image data which was used as a design template and spatial organiser for the installation. With the specially programmed software, I produced a large number of results by varying the parameters in fixed steps, all registered with screen grabs. The source material was analysed and I selected a few interesting instances. I ended up choosing one instance because it engaged the whole gallery space. It was spread the most and it was distributed so that it generated interesting and varied structures with varying densities. The distribution and variation was potentially well-suited to informing the distribution of spatial construct, audio space and actor. This selection was based on a subjective forecast of the potential of the chosen material; I imagined the usefulness for a design development.

The material was two-dimensional and in the first experiments I simply started to work with the material graphically and map it into the space (Figure 176). Several different ways of using the source material to inform the design of the gallery space were investigated (Figure 177).
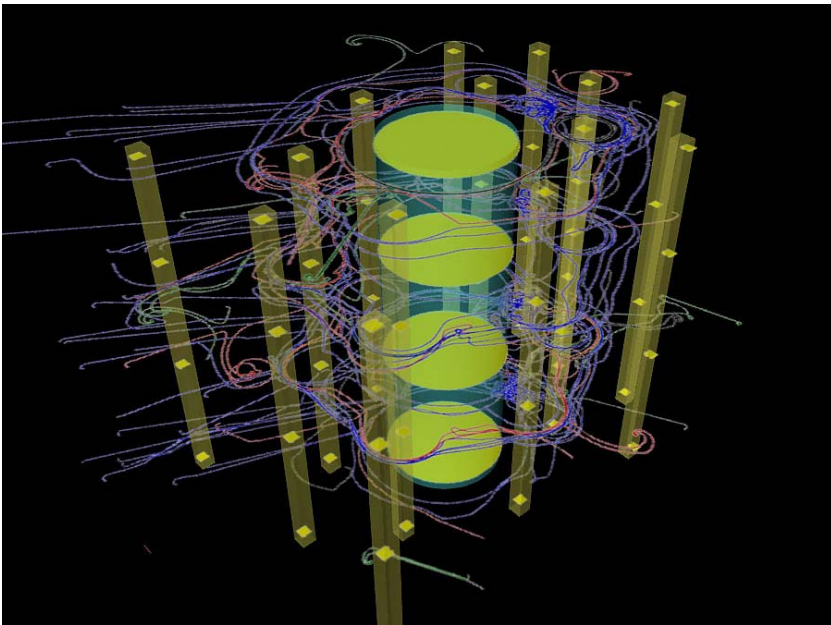
Figure 176 First attempt to work with a generic gallery space for the performance. Different instances from the source material are mapped in planes throughout the height of the space.

Figure 177 Different interpretations and designs from the source material were investigated. The implementation of a source material is not obvious? and several trials were needed to reach the final solution. Practical considerations like the ease and cost of construction and rebuilding were crucial. In the end, a simplified version of the solution on the left was chosen. The tubular structure, inspired by the Chamberworks installation, created a spatial structure that was usable for both physical and auditive space. The Ambisonic system was programmed with the spatial information from the tubular constructs so that the sound-space would in some cases follow the tubular space.

Physical modelling

A stage of physical modelling was introduced but the documentation from this stage has unfortunately been lost. The stage involved a large number of collaborators and triggered the trial of many concepts and approaches and fruitful discussions, which in the end influenced my final decision for the selected design approach. The physical modelling phase had in this case more the nature of a phase of simmering and consolidation rather than having direct influence on the final design. This was not a planned development of the project, but networked and distant processes often have their own dynamics. The process benefits from being slightly out of control.

Direct modelling

The digital model of the installation was partly modelled directly. The output from the simulation was only 2D and the mapping in space was done through direct modelling in a complete site model of the central station.

The geometries informed by the template were negotiated in terms of the complex geometry of the site.

During the project, the original site was abandoned and a new possibility for a first set-up was the main entrance hall of the Oslo Central Station. This project implied a total remodelling of the sound system. But at this stage we started to think about recycling the installation. We therefore tested the negotiation of the original design onto the new site for the installation (Figure 178).

Figure 178 Merged image of CAD model of central station with installation and real-life image.

Data recoding

The final digital model of the installation was via VRML-format translated into spatialisation data to be fed into the software that controlled the ambisonics system. The model was cleaned, all unnecessary elements were removed and the remaining trajectories, which were the most important elements where reduced to polylines and then exported in VRML format. The VRML data is organised as a data array that is easy read in ASCI-format by a normal text editor. Therefore the data is easy to modify and translate into another format like the data needed to spatialise the sound system. The VRML model was also a visual aid and needed for orientation. At certain stages, the amount of digital design tools involved was large including

special composing, sound and sound spatialisation software, where the interface between physical representation and spatialisation was best done via a spread sheet format (Figure 179).

	A collision-start-x1	B collision-start-y1	D collision-start-x2	E collision-start-x2
3	-8,65	-11,83	-7,3	-11,01
4	-8,65	-11,83	-7,3	-11,01
5	-8,01	-6,36	-6,99	-6,47
6	1,13	-6,42	2,66	-6,9
7	2,16	-6,53	0,96	-5,53
8	2,48	-6,14	1,98	-5,8
9	1,96	-5,71	1,51	-6,15
10	-2,06	-3,41	-1,91	-4,83
11	-0,95	-3,97	0,37	-4,72
12	-0,67	-3,73	0,18	-4,4
13	-0,04	-3,57	-0,7	-3,68
14	-5,35	-1,34	-4,24	-1,46
15	-4,09	0,51	-4,08	-0,99
16	-5,23	-0,92	-4,07	-0,96
17	-4,53	-1,06	-4,1	0,48
18	-4,1	0,39	-4,91	-0,89
19	-5,12	-0,8	-4,11	0,33
20	-4,1	-0,42	-3,59	-0,18
21	-4,09	-0,51	-4,34	-0,15
22	-4,49	-0,27	-4,09	-0,51
23	-3,97	-0,22	-4,08	-0,6
24	-4,01	-0,92	-3,28	-2,26
25	-5,55	-1,64	-4,12	-1,07
26	-4,19	-1,11	-5,28	-2,23
27	-5,38	-1,81	-4,3	-1,17
28	-4,56	-1,32	-5,54	-1,9
29	-4,71	1,1	-3,77	1,15
30	-5,77	-1,73	-6,98	-0,75
31	-5,87	-1,91	-6,97	-0,77
32	-4,64	-1,62	-3,74	-1,36
33	-6	-1,93	-6,91	-0,89
34	-4,53	1,68	-3,55	1,76
35	-4,53	1,68	-3,55	1,76

multiseg1.xls

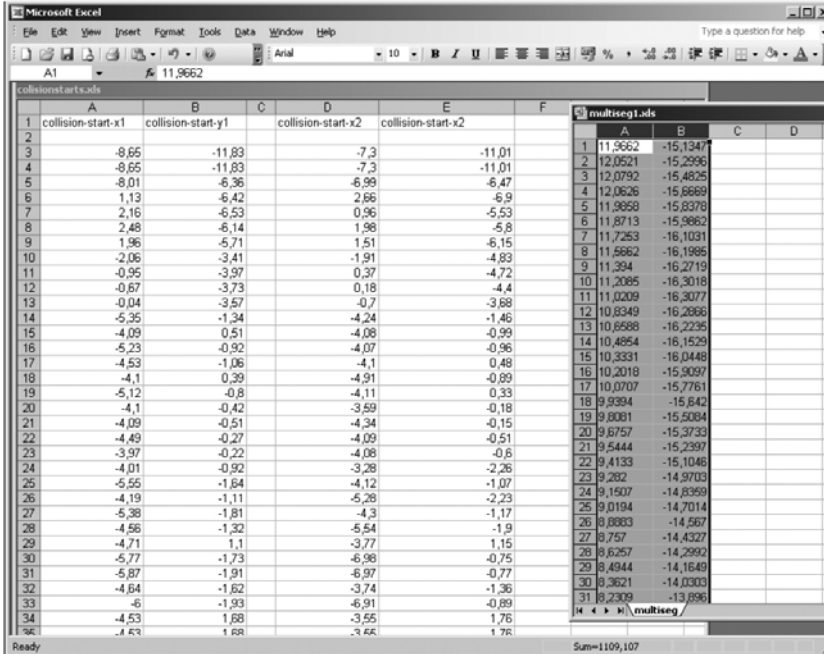|	A	B
1	11,9662	-15,1347
2	12,0521	-15,2996
3	12,0792	-15,4825
4	12,0626	-15,6669
5	11,9858	-15,8378
6	11,8713	-15,9862
7	11,7253	-16,1031
8	11,5662	-16,1985
9	11,394	-16,2719
10	11,2085	-16,3018
11	11,0209	-16,3077
12	10,8349	-16,2866
13	10,6588	-16,2235
14	10,4854	-16,1529
15	10,3331	-16,0448
16	10,2018	-15,9097
17	10,0707	-15,7761
18	9,9394	-15,642
19	9,8081	-15,5084
20	9,6757	-15,3733
21	9,5444	-15,2397
22	9,4133	-15,1046
23	9,282	-14,9703
24	9,1507	-14,8359
25	9,0194	-14,7014
26	8,8883	-14,567
27	8,757	-14,4327
28	8,6257	-14,2992
29	8,4944	-14,1649
30	8,3621	-14,0303
31	8,2309	-13,896

Figure 179 The translation between the physical spatialisation and sound spatialisation was achieved via a spread sheet format. This represents the information that is shared by both representation forms. The information was derived from the final physical model and was used as spatialisation information in the ambisonic sound system.

Complex geometries: advantage of using 3D-tools for prefab and recycling

The elements that were first designed for the Central Station setup were prefabricated in a metal workshop. To do this we needed exact drawings with measurements. A large amount of construction drawings and tables with logistic information was produced (Figure 181). We now had a series of elements and the information about how they were interconnected.
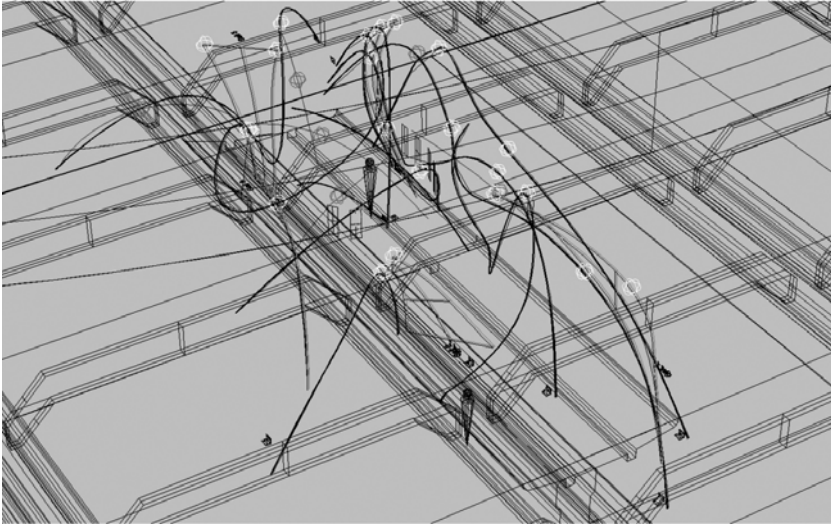
Figure 180 Screen grab from Rhino3D showing the design for the Oslo Central Station. The existing building elements are shown and the connection points for the suspension of the installation.
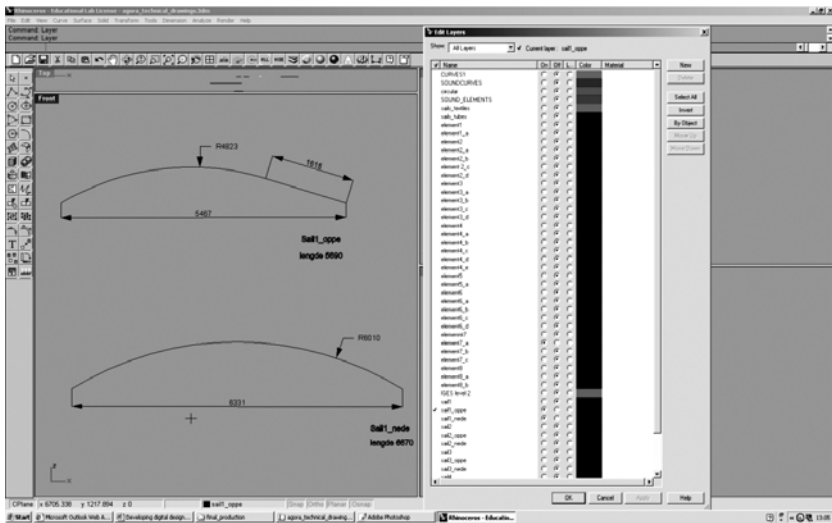

Figure 181 Construction drawings. Each layer represents one element, only one element visible.

The prefabricated elements from the station were recycled in the Black Box Theatre. This recycling was also done in a computer model where the

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elements were negotiated in terms of the design template and the new space. So the only thing we had to alter was the logistics of how the elements were actually connected. The complexity of the design allows for an infinite number of variations assembling the elements in ever new ways, despite their specificity, unlike other module systems which are based on the infinite repetition of a limited number of identical elements.

During the recycling process, we went through an almost complete trial set-up in a specially hired space for tests and rehearsals.


Figure 182 The bridge, looking towards the ambisonic cube. Only two of the eight black speakers are visible to the left top and lower part. In the center of the right half in front of the textile surface one can see one of the electronic hammers and the cylindrical rod connected to it.

Figure 183 The bridge, looking in the opposite direction from the image above. One of the ambisonic loudspeakers can be seen in the centre of the image. Two plastic membranes are visible at the top in the left half of the image.

The blurring of synthetic sound distributed over loud speakers and physical sound elements including the natural sound-scape of the central station was achieved by introducing several crossing elements. One was the mixing of sound sources in the taped and programmed sound. Another was the use of membranes that were fed with sounds from the computer. They were physical sound elements, similar to loud speakers but with a much stronger filtering capacity. Also the cylinder bells with long aluminium rods contributed to the bridging of the sound-scapes.
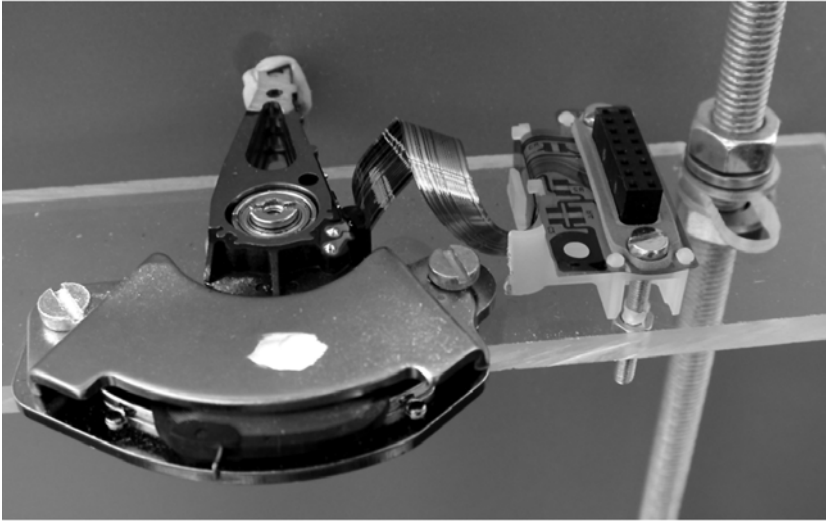
Figure 184 The sound active membranes were activated with parts from old hard disks that were fed with computer signals. On a scale from the synthetic to the physical, they were between the ambisonic loudspeaker system and the cylindrical bells.
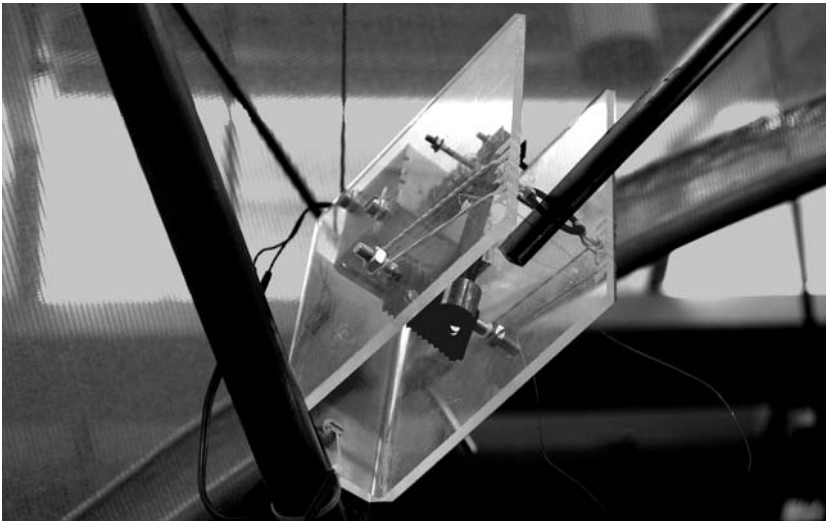
Figure 185 Cylinder bells. The sound active aluminum rods were activated with small computer-monitored solenoid hammers. Their level of activity was influenced by an infrared trigger. On a scale from the synthetic to the real life sounds, these sound generators would be between the synthetic sounds and the natural sound-scape of the station.

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Hybridization as a strategy

The effects of this way of working was in many cases an achieved synergy and jumps in the design process. The different categories were applied during the design process in various ways and combined with traditional drawing and CAD and physical model building. Some techniques, like Direct Modelling, appeared frequently and in repeated cycles. It was also central in the negotiation necessary for recycling the installation from the first to the second event. Others were conducted in very distinctive phases, like the simulation that was produced at the beginning of the project. Still others, like the appliance of the simulation material as spatial organiser and design template, were repeated in several distinctive modelling events.

Composite modelling

In AGORA, composite modelling techniques were developed for the production of the physical installation. Such techniques are obviously much more frequent in musical production and are apparent in the compositions for both installations. The installation was designed on the basis of the agent animation but some aspects were simultaneously designed directly. This was especially the case with the spatial distribution along the z-axis, since the animation did not contain any 3-dimensional information. This was a composite technique between on the one hand the rigid tracing of a source material, and on the other an explicit designerly approach to spatial design.

Switching and translation

The hybrid process implies switching between media and methods. The switching between ways of working has a potential to speed up the progress and to trigger leaps. Changing media or technique helps to see other aspects of the design and will in many cases help to lead the process out of dead ends. The hybridization strategy involving switching and translation as described here intends to take full advantage of these effects. The hybridization strategy involved a network between techniques, methods and disciplines. Information was channelled between the different representations and between designers and composer.
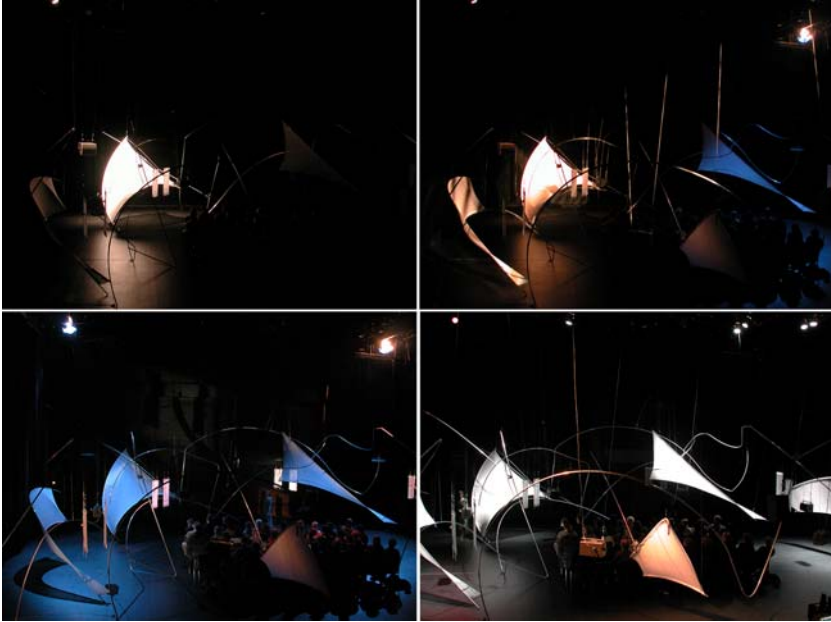
*Figure 186 Performance at the Black Box Theatre in Oslo. The dynamic lighting
system altered the impression of the space substantially.*

Figure 187 Soprano singer Kristin Norderval

Figure 188 The soprano singer Kristin Norderval acts as a spatial cursor through the performance.

Figure 189 Engaging with the space and constantly shifting from background, middle-ground to foreground.

Figure 190 Long phases were without soprano singer. The space itself played the role of focus.

Looking back at AGORA, it was a truly hybrid process which was driven by, and benefited from, its complexity, the range of elements involved and the richness of its content. It benefited from interdisciplinary cooperation and from the tolerance of loss of total control. This tolerance was nevertheless paired with high ambitions and at times hard negotiations.

Renewing the process
An important hybridization strategy is the ever ongoing invention of new variations of the design process. The exploration of computer-aided generative techniques, including the development of ever new ways of working, is one precondition to avoiding eroding the emergent element of the process due to refining a fixed pallet of tools. Hybridization is not only dependent on being able to develop a set of tools and switch between them but also on the frequent refreshment and replacement of the tools, concepts for the process, and the creation and merging of elements.

Hybrid processes as complexity management
Hybridization strategies do not only involve techniques and strategies but might also be expanded to include the issue of cooperation in complex

projects. I would argue that many such processes are today over-managed. A tight management is necessary in crucial engineering projects but not necessary in creative design projects. On the contrary, tight management will in many cases kill the process. Instead, a hybridization of different people, expertises, positions and expressions will reduce the need for control and allow for a climate of emergence. Such processes are not fully controlled by any individual. Time-consuming negotiation to achieve consensus is replaced with the acceptance of emergence when the products of the process are taken over by others. This type of process has successfully been demonstrated by our collaboration in OCEAN NORTH. Hybridization demands a loosening of the individual ownership of the design product but at the same time demands an acknowledgment of individual domains within the design process. The computer and communication technology is crucial in such processes. The hybrid process is a natural result of the computer-aided creative design process.

Hybridization of design processes can successfully be lifted towards a consciously developed strategy and I think there is a great potential to develop these processes further.

6. Summary and conclusions

I now turn to summarizing what I feel are the most important conclusions we can draw from the work presented in this thesis. Two main achievements emerge:

- The thesis contributes to the investigation into experimental design with computers. It contributes to the mapping and categorisation of the field and suggests new ways of conceptualising and developing the field of creative design computing.
- The thesis demonstrates a possible basis for practice-based design research. It brings the design practice into focus and establishes individual designers' reflective engagement in design practice as an investigation tool equally as important as theorizing and writing are regarded to be. The thesis thus contributes to the argument for research through design.

6.1. PRINCIPLES, CONCEPTS AND METHODS FOR CREATIVE DESIGN COMPUTING

In this thesis, I have proposed principles for a practitioner approach to creativity, and I have addressed many concepts and methods for creative design computing. I briefly reiterate my core principles, followed by a reprise of the main concepts that I have introduced.

Principles for a practitioner approach to creativity
An important basis and argument in the thesis is the conclusion that a pragmatic and action-oriented approach to the research of creativity is feasible. Creativity is not a stable phenomenon, but a product of cultural perspectives. We can alter creativity through practice. Practice-based design research is an important means to achieve the active exploration and construction of creativity.

Concepts for developing new design techniques
The basis for the development of new design techniques is an experimental attitude which allows for a playful approach to design computing. The exploration of the possibilities is absolutely dependent on an explorative practice. Computer emergence, visual thinking and the exploitation of the flexibility of data are all central issues.

Ways of working
 The invention, distinguishing, labelling and sorting of concepts and techniques in creative design computing are efficient means to establish a feedback loop that generates theory in the field and that fuels the design practice.

Ways of thinking
 Our intentions in the field of creative design computing are manifold and come together in more complex and intertwined design processes. The systematisation of and strategies for these processes have the potential to bring the field forward.

Below, I summarise the most central and important concepts introduced throughout thesis..

Thinking through design practice: An inspirational playful design approach is very useful when exploring the potential in generative and creative design computing.

The importance of the source material and finding strategies: The thesis supports a concept where the use of generic or specific source material is an important initiating force for a design process. From this follows the importance of exploration, discovery and finding strategies.

Breaking schemata: I suggest that generative digital computing can be used to enhance creativity when we allow emergent design to suggest unforeseen and unanticipated results.

Abstraction and generative diagramming: One of the main claims is that to exploit the computer as a generative tool, we need to work on an abstract diagrammatic level. This is illustrated throughout the thesis with cases that demonstrate the movement from abstract source material to concrete finalisation.

Visual thinking: I claim that visual thinking is a precondition to working in an abstract and diagrammatic way. Visual analysis and the resulting processing of generative material into new interpretations are central.

Virtual phenomena: I propose a finding technique that is focused on finding virtual phenomena in dynamic generative material. Such a finding technique emphasises events and time-based relations. The results can be used as relational principles in design.

Time-based design: The thesis reports a series of experiments with time-based design. Both design according to time and the design of time itself are explored.

Mis-use strategy: This refers to the implementation and redefinition of software programs in areas other than their originally intended usage. By using software programs in different ways than those for which they were intended, we can find an extensive range of tools for experimental digital design. The choice of tool and strategy of use are important factors in the development of digital design techniques.

Working with and not against the technology: An important issue concerns the resistance and bias that are inherent in software programs and digital technology in general. Spline surfaces have a different influence on the design process than polygons and the final result will differ. Numerically-controlled grinding machines leave traces on the surfaces of the materials. All of the different rapid prototyping technologies have their material limitations and advantages. STL-files tend to leave patterns of polygons on the objects; selective laser sintering creates 'topo-curves' on the surfaces. I argue that all these effects and constraints should be allowed to be influential forces in the design process. These constitute the traces of the digital technology as an emergent potential in the digital process.

The role of processing: The thesis argues for the value of processing the information generated during the design process in order to reach new representations (recoding) and new interpretations (translation).

Pre and post rationalisation: An important issue is the negotiation of pre-existing forces and conditions into the generative process from the start. The development of realisation strategies is also at stake. Here the distinction between scaffolds and templates are central.

Collaboration: An important aspect of the thesis and its results is that it is built on collaboration. Collaboration is not only a benefit but was a necessity for this work. It is also used as a means of negotiating individual control in the design process.

The hybrid process: The use of a wide range of techniques and concepts and experimental design methods are important ingredients in inclusive processes. I suggest a next level where the combination and shifting between

these ingredients is strategised to achieve a higher level of output and synergy. I call this the hybrid process.

Methodological contributions towards practice-based research through design

The approach to methodology in this study has been manifold. In particular, grounded theory has been an inspiration. But the highly specific methods suggested from grounded theory have proved to be too rigid, and thus a looser and less resource-intensive approach needed to be developed for the designing practices under development and reflection in this research. The justification for the approach developed is found on the basis of the need to maintain the design practice as an important element in the research.

The categorisation and conceptualisation demonstrated here is still under continuous development? The categorisation offered in this thesis is therefore is not meant to be taken as finite. Even at this early stage, results of categorisation have proved to be useful. My intention was not to establish an authorative categorization that would be used as the largely adopted vocabulary of digital design. Categorization is used here as a tool to map the field and to build theory and methods for digital designing. Further investigations conducted by other practitioners will hopefully fill in the picture and suggest other techniques not mentioned here. Future explorations may pick up on the topics listed above. Hopefully other concepts will be invented and explored.

From this study in design research, my major methodological contributions towards practice-based research through design can be summarised as follows.

- A view on creativity from the perspective of action (the practitioners perspective)
- A prescription of how to alter creative processes by means of computer technology.
- A mapping of a long series of techniques and intentional strategies that can be taken up by others, altered and developed further.
- An inspirational toolbox of both pragmatic / practice-based techniques and concepts.
- The concepts of a hybrid process and the strategies for hybridization of processes in digital designing

Is a new type of creativity emerging from the use of computers in design?

The emerging creative techniques inspired by computer technology have led to a more complex, inclusive and varied design process. The computer has not replaced all existing design techniques, but rather widened the scope and the available ways of working with design projects. The different techniques, tools and methods together create new synergies. This is a development that happens, to a certain degree, independent of the development of a methodology for the digital age. However, the potential of the many different techniques in digital modelling in relation to other techniques is far from fully explored.

Digital computing has definitely altered the design process and creative processes in general. The re-use of material is a well-known contemporary phenomenon, especially apparent in popular music. Design processes have, in general, been freed from many laborious and time-consuming elements and what used to be reserved for experts only has migrated to an increasing number of other professionals and to private homes. The effect is that designers and other creative people cross borders more easily and that they use a wider range of techniques and possibilities than before. This again leads to more complex and manifold creative processes. The combination of techniques and technologies has a potential to enrich the creative process, especially if we start to exploit the potential in these hybrid processes. In a sense we have only seen the beginning of a development. Based on this, we can conclude that a new type of creativity is indeed emerging from digital design.

In the introduction to this research inquiry, I asked three provocative questions:

- Can we still talk about a creative process when significant parts of the output are generated by a machine?
- Can we still claim to be designers when our level of control is reduced?
- Can we be credited for accidents?

I believe that I have demonstrated that digital emergence and individuality can go hand in hand. In fact, digital generative techniques can support individual creativity in a productive way. The digital techniques can lead to enriched and inclusive design processes which are challenging and inspiring for the individual designer and for collaborative work in design. Digital design triggers a drive to cultivate synergies and creativity that come from multidisciplinary or transdisciplinary collaborations and international

collaborations like OCEAN NORTH, establishing the practice of the different participants as the basis for digital creativity.

The issue of control is not merely a question of which parts of the design process are taken over, but rather a matter of shifting control to other parts of the process. The production of a large number of instances can be said to provide a greater level of control. Losing control is a central aspect of a creative process. Strategising the loss of control through digital generative design results in new kinds of generative source material. We can therefore claim that the digital techniques may actually contribute in a large degree to the creative process.

6.3. A PRACTICE AS THE FIELD FOR AN INVESTIGATION

The approach in this thesis hopefully contributes to the development of practice-based research. This approach is based on simultaneous production and reflection.
Besides my main objective to describe our practice in a systematised way, I have had a secondary agenda. I wish to establish a methodological space for first-person practice-based studies. I hope that I have achieved this by demonstrating a level of flexibility and systematisation that is appropriate. Since this is not a dissertation on research methods, I limited the argumentation for this position at the beginning of this research as much as I thought was possible, but the need to challenge the limitations of established methodology became evident during the project. The danger of sabotaging an explorative project through too tight methodological restraint was given more weight than the satisfaction of a more conservative methodology. This project implies standing forward as a design researcher, practitioner researcher and researching practitioner. Securing against all possible criticism renders an individual practice-based research project impossible. I believe that a small scale, particular first-person practice-based research project may demonstrate that it can generate very valuable knowledge as long as we allow an appropriate framework for such investigations.

6.4. SUGGESTIONS FOR FURTHER STUDIES

There are several fields and concepts that are very suitable for further development and study:

Pre-rationalisation and parameterisation
A very interesting topic would be to work on creating additional techniques and approaches that combine the way an artist works with source material and the way an engineer works with emergent design. The artist uses a

source material as an independent starting point for the development of a process, whereas the engineer collects a large number of input parameters and constructs a design machine that generates solutions from the input (parametric design). The pre-rationalisation strategies that I have proposed are forms of emergent design that live between those two approaches. I think there is a potential to investigate this further.

Post-rationalisation and realisation strategies
From the development of pre-rationalisation follows the implementation of important frameworks and conditions at the beginning of the process. This has a great influence on the realisation techniques that follow a generative process. The development of techniques along the lines that I have described (scaffolding, templating, modelling) also needs further investigation. Negotiation techniques could also be developed further.

Hybridisation
The further development of techniques and methods for the organisation and interlinking of the hybrid process is possibly the most interesting aspect. The hybrid process takes the investigation to a higher level where communication, co-operation and complex processes are organised.

Appendix
For an online appendix to this thesis go to
www.aho.no/staff/bs/phd/digtech/app.html

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