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Design Credo:
The making of design tools as a personal theory building process

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Aalto University School of Arts, Design and Architecture

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Prologue

Perspective drawing

A picture of physical objects can be made by tracing their outlines through a transparent glass, while keeping the eye position fixed. The resulting image is an approximation of the way the objects appear from that one viewpoint. These images can be drawn on paper without any physical objects to be traced, by using a perspective method (Figure 1). Using projective lines, the viewpoint image can be created by using plans and elevations as sources.

Another approach to perspective drawing is the perspective sketch (Figure 2). Objects can be drawn without using definite plans and source drawings. In contrast to the strict methodical procedure, a different skill is involved when sketching in this manner.

Whereas the strict method transforms a known shape into a viewpoint image, the one-point perspective sketch initiates new form that had no precedent. Although the vanishing point becomes useful in setting up the sketch, even this can be dispensed with. In the extreme, the perspective sketch is an automatic drawing guided by the perspective principle. Out of the many possible, these two polarities represent two different attitudes to creating form. One can start with a plan drawing and use the perspective method to clarify the appearance, and one can begin with an eye-level sketch and derive plans and sections from there.

Traditionally, designers have worked with both methods.[1] Perspective manuals represent a tradition of adapting perspective methods to suit better the diverse contexts in different design fields or even unique situations. An industrial designer needs a rapid way to assess the appearance of a product idea. The interior designer needs a way to convey the look and feel of inside space. Any designer benefits from an ability to quickly elaborate and use the drawings for advancing their thinking. Rules of thumb and dedicated machines exist for the practical purpose of making illus-

[1] I have utilized John Pile's exposition from the book *Perspective for interior designers* (1985). The synthesizing drawing is more in line with William Kirby Lockard's ideas about perspective in *Design drawing* (1982), where the eye-level sketch is connected to an experiential understanding of space. Jay Doblin's book *Perspective: a new system for designers* (1956), aimed primarily towards industrial designers, was also influential as it discusses the cube as a basis for freehand sketches. These perspectives are discussed in chapter four.

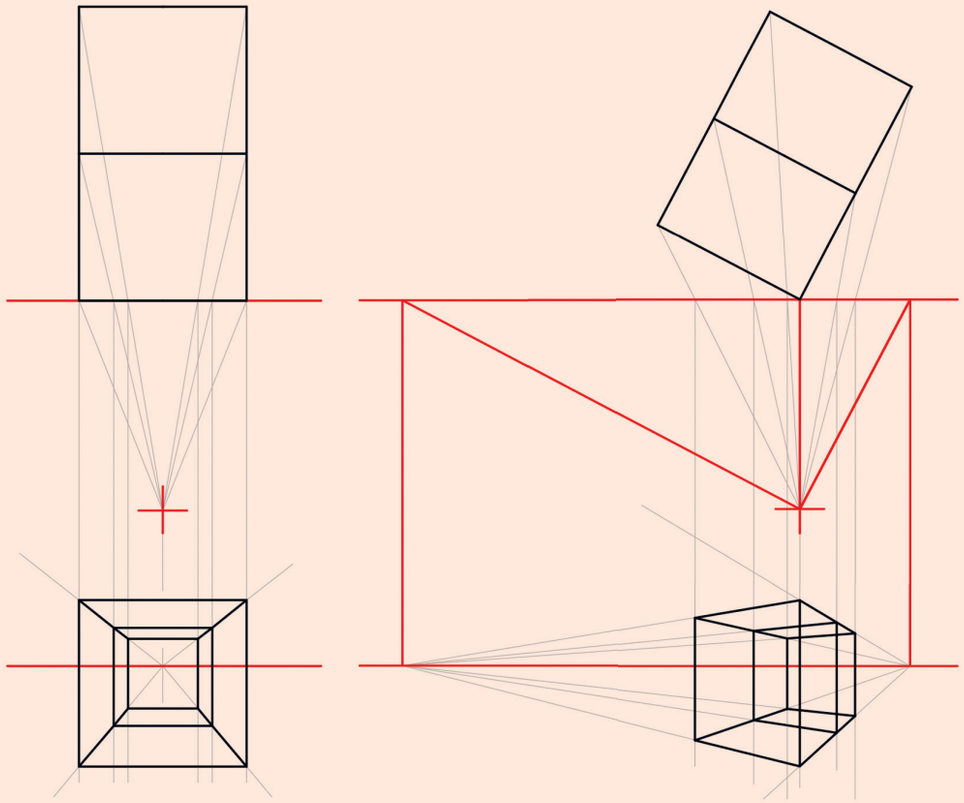
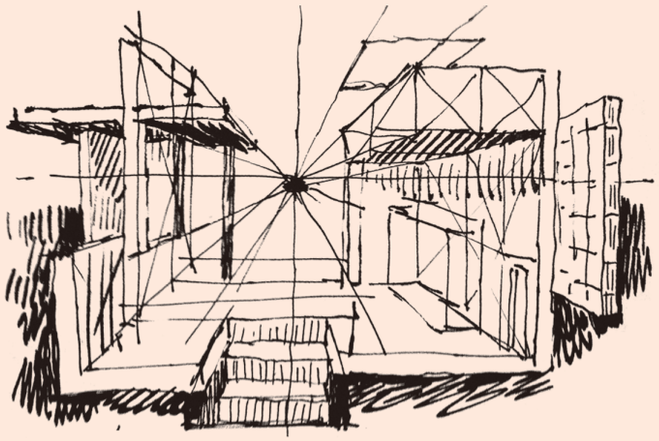


Figure 1

A simplified perspective method based on a plan drawing. When the object shapes are already known, a perspective drawing can be drawn methodically.

Figure 2

The vanishing point helps guide a generative sketch drawing. The forms are created as the sketch proceeds.



trations and sketches. Perspective drawing manuals for designers stress that the rigid method is a way for learning to draw objects in free hand. The authors saw freehand skill as more indispensable to the designer and closer to actual designing than the rigid method. As the designer learns to draw cubes from any angle, he or she can draw any form, letting the grid underlie the drawing just as the vanishing point would underlie the perspective. For the experienced sketcher, the rigid method and its assistive lines begin to vanish, replaced by the more flexible idea of perspective as one possible means for generating form.[2]

It would be tempting to say that the freehand sketch describes all that is essential to creative design, letting the rigid method stand for everything that is mechanical and mindless. But seeing the perspective method as a design in itself opens up another direction. For those who are familiar with the methods, it is simple to experiment with modified projections and put new ideas to the test. One-point perspective is a special case that may be further modified into

[2] The book *Basic principles of design* (Maier, 1980) describes a foundational drawing course as part of the curriculum in the design school of Basel. The students proceeded by drawing series of cubes from different angles, extending to cylinders and ultimately complex objects. Over time, the students would learn a way to construe a proposal in three dimensions quickly, yet accurately. "The drawing procedure is comparable to that of the carpenter or sculptor, who finds his mental image in roughly formed material." (Maier, 1980, 25)

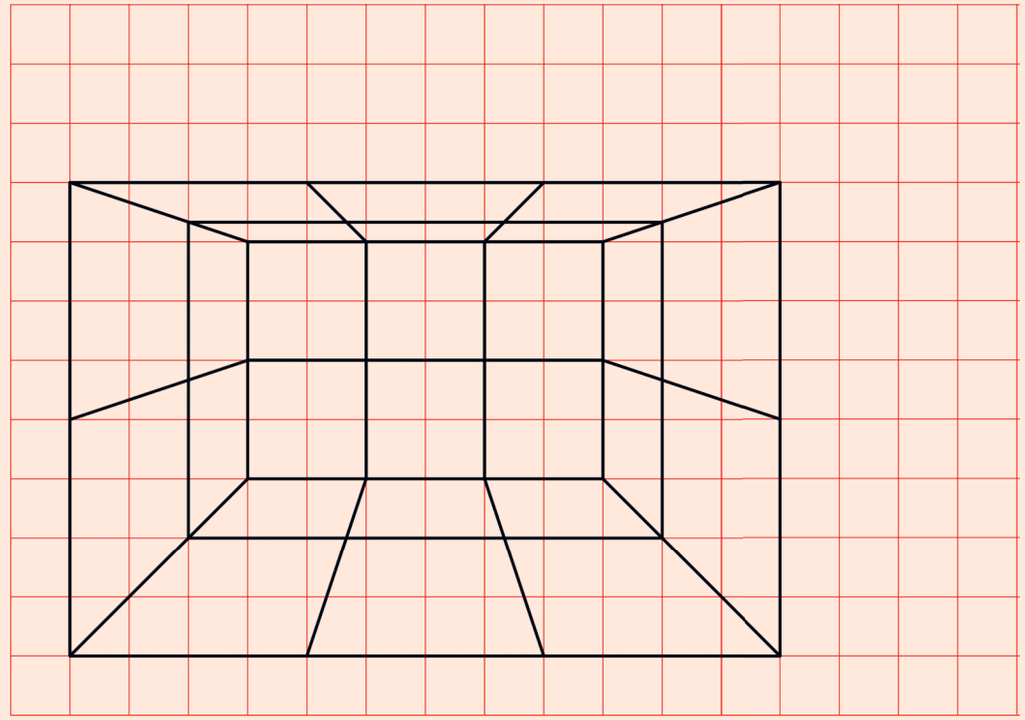


Figure 3

A modification to plan drawing method is used to make a template for sketching a room. One square can be decided to be 120 cm across, helping establish common room dimensions. The perspective method on paper is easy to modify and adapt for specific situations.

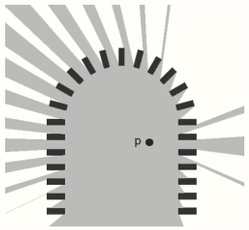
room templates, should the need arise (Figure 3). Modifying the perspective method and coming up with ways to apply it is in itself creative work, as it sets up possibilities for the later stage.

Before the invention of the computers, the means and ways of drawing were tools that clearly arose from the profession of design. The more comprehensive manuals were written by practical-minded designers who learned through experience, and attempted to deliver their understanding in a written form, accompanied with examples and illustrations. They also justified their methods by bridging their experiences and beliefs to then-current findings in perceptual psychology and design theory. Could the perspective method serve as a metaphor for creating ideas through design and distributing the results among a community of practitioners, from designers to designers? Could this idea be revised in a way that treats different tools more inclusively, not just drawing and modelling?

Figures 4, 9–11

Figure 4

The three artefacts created in this thesis project. Each is a different take towards the topic of designing space. They are interpreted as different stages in the development and expansion in the author's personal theory of space.



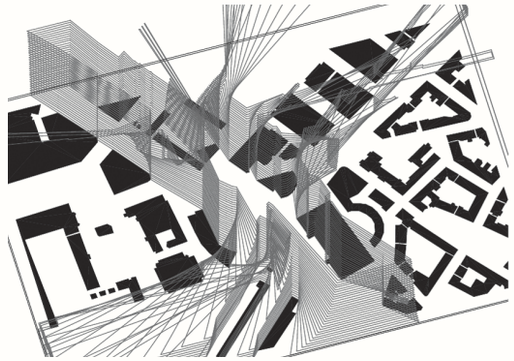
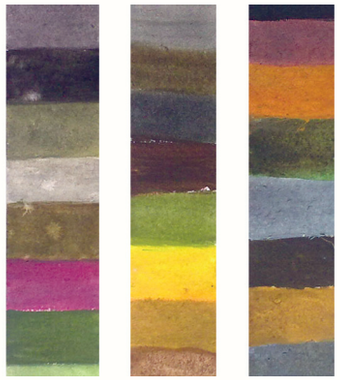


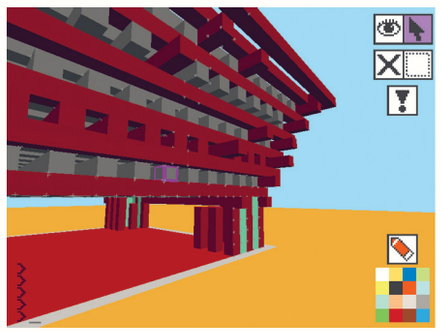
Figure 9

The first artefact, *Fields of visibility* and an example of a view cone. The visualisation displays the motion of a view cone in a plan drawing.

Figure 10

Left: The second artefact is a hand-held tool, a colour pointer device for recording colour readings from the environment. Right: Hand-painted colour slips are an alternate means for collecting the colours.





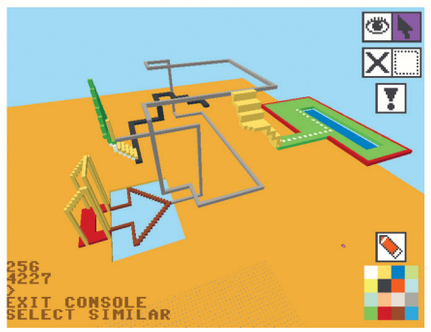


Figure 11

Tile modeller: Outcomes made with the third design tool. These examples were made by design students using the software.

1. Introduction

1.1 Motives and background

I present in this thesis an understanding of spatial design tools. This understanding is built through making design artefacts, which are used to advance the topic from different angles. Three artefact cases are examined in detail. First is a computer visualisation about motion in space, the second artefact is a hand-held tool, whereas the final case discusses modelling and drawing. As the three artefacts are built, each has brought to light different aspects of how spatial design thinking may advance.

The thesis project has its germ in my past experience and a personal quest. As a graduate from a furniture and spatial design program, I was fascinated with the ways available tools and materials could be suggestive when both deciding what to design and how the outcome unfolds. Already before that, studying woodcraft helped me to appreciate how not only materials but available machine workshop tools suggest outcomes. Although not obvious to me at the time, from the simple observation about the machines it is not a big leap to think about the role of drawings, computer programs or other underlying principles as influencing and guiding design. While studying furniture and spatial design, my interest also shifted towards these things. This meant a more definite interest towards design drawing methods and computer modelling software, but also a growing curiosity about design literature.

During my studies I encountered many beliefs and ideas about designing, how to design and what design is. These I not only heard from educators but also found in old books. As a beginner, I hoped for some definite advice on how to design, and it was natural for me to turn to books for answers. Diverse literature, now mostly forgotten to me, gave various confused directions which at the time were difficult to position or assimilate. Perhaps my earliest ideas about the meaning of "design theory" were influenced by old archi-

tectural books. At the time it seemed that theory was just a matter of having measures and dimensions for each furniture or room type. Someone, somewhere, had figured the numbers out. More fascinating were the harmonious proportions, modular systems or classical orders in old books. I wondered why something similar did not weigh heavier in design today and why such ideas seemed less discussed. As I have now been able to concentrate on research, these mysteries have become clearer to me. Although theories and opinions about space, experience and perception abounded in old architectural books, it dawned on me that many of these ideas about space were not really theories in a strict sense. These writings were opinion pieces, no matter how widespread the beliefs were. Still, designers and architects in past times worked with these ideas and beliefs, as strong convictions nourishing their work. They were also "machines" for guiding and suggesting design, and as machines they were artificial, designed things.

In this project, I have chosen to examine the development of my understanding of how space and form is created. I have pursued this through building three different design tools. (Figure 4) Each of the three cases is used to probe the topic from a different angle. Understanding is accumulated through these different vantage points. At the same time, my personal theory has become refined as I have reflected on the meaning of these artefacts and what they, as objects, tell me about the beliefs and motivations that guided their creation. Acquired skills with drawing, painting and programming stimulated me to turn toward both computer programming and traditional mediums of drawing and building. The first artefact is an attempt to build a visualisation of a theoretical idea about motion in space, and as such is a more stand alone object than a tool. The second artefact is a hand-held tool that defines the designer's relation to a site.

Figure 4

The third artefact is a modelling program that enforces tiles as the foundational structure for the design. This is discussed in relation to design drawing.

Personal belief means a personal theory, such as an artistic credo.[3] A designer is not likely to use a combination of well-understood academic theory and so-called practical skills. The designer's personal knowledge is a combination of literature read, influences and all past experience. It is in this light that tool building becomes also a way of personal theory building. To build a design tool is to believe in some way that it is beneficial and to attempt an articulation of this belief. In larger scale, the credo encompasses the belief that material tools and artefact can have a central role in design, and that their study is a worthy pursuit. As a practice-led research project, the practical work has been allowed to guide the research and the reading of theory. The text is an account of looking back at the artefacts and the motives that guided their creation, how the building process transformed this understanding and what insights resulted from each case. Besides dissecting each case in this way, it has been possible to look back at the overall thesis project in similar manner.

[3] According to the Oxford English Dictionary the word credo comes from latin, meaning "I believe". A creed is described as "A system of belief in general; a set of opinions on any subject, e.g. politics or science."

1.2 Central concepts in the thesis

The diagram below (Figure 5) shows the research focus as an intersection of broader topics, derived from design and research literature. Central concepts of this dissertation are given below, just as is the background it stems from and the contents of the thesis. The intersection and the concepts serve as the outline for the project. Partly the chosen concepts work as explanatory devices for making sense of design cases in a consistent way, partly they have aided in narrowing the overall thesis topic. After the brief concept definitions, the themes will be elaborated further in the introductory chapter, and returned to in each of the main chapters.

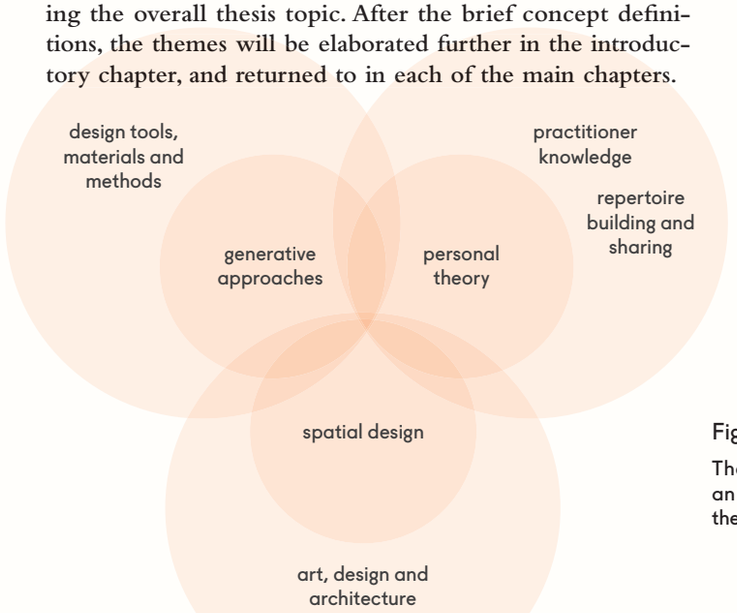


Figure 5

The thesis focal area as an intersection of broader themes.

The overall research approach is outlined as a practice-led research project, where practical skills and knowing become integrated in a research project via making a series of artefacts. The major objective is to discuss the artefact cases in terms of personal theory building. The project is focused on the concept of generation and generative approaches in design, and excludes broader contexts and other roles that design tools may have. Lastly, the subject matter addressed in the artefacts and tools relates to spatial design tasks in an art and design context, understood as a generative design process.

Practice-led research and research through design

Social scientist Donald Schön has given an outline for defining practitioner knowledge (Schön, 1991). He suggested a number of ways a practitioner, with an insider view to the practice, could engage in research more systematically. Repertoire building forms part of such research. A practitioner has a repertoire, which is his or her whole past experience and knowledge at that point (Ibid., 138). I am especially interested in how knowledge emerges from a retrospective analysis of these experiences, a central aim in practice-led research. Practice-led and practice-based research approaches have been advocated by artists and designers who have wanted to include design work as part of their research project. By reporting on the practical design work he or she has done, the designing researcher is contributing to a wider repertoire from which other researchers and designers can draw from. In this thesis, I define myself as a designing researcher, not a design practitioner. Knowledge in this research project is seen in Schön's terms. I have followed and adapted Schön's concepts, relating them to available literature in practice-led research.

The definitions of practice-based and practice-led are still open to some debate. Linda Candy has suggested that practice-led, as opposed to practice-based, is research which primarily leads to new understandings about practice. The resulting knowledge would have operational significance for that practice. The inclusion of the creative work as objects is not required for understanding the thesis or the examination of the research. (Candy, 2006.) This definition emphasises the existence of a practice to which the work contributes to. Arts and Humanities Research Council in the United Kingdom has reviewed approaches to practice-led research and arrived at a somewhat broader definition. In the review report it is concluded that it is a kind of research where creative practices of art, design or architecture play an instrumental part in an inquiry. It is stressed that the contribution that the practical work makes to knowledge should be explained. (Rust et al., 2007, 11.)

Practice-led research is here understood as a mode of doing research through design, a position most famously proposed by Christopher Frayling (1993). Frayling wanted to differentiate research through design from research into and for design. It is clear that design can be studied from the outside as a topic, and that designers often need to do background work resembling research in order to advance their work. Materials research, development work and action research would instead fit into research through design. (Frayling, 1993). Frayling's formulation has also attracted criticism. The category of research through design is seen as potential but in no way proven to exist. Frayling's article was seen as offering little in terms of a practicable definition for the proposed category, and the critics found little convincing research work under the heading of research through design. (Durling, Friedman and Gutherson 2002.) The critique seems to hang on a requirement of a clear definition for research through design. In absence of a definition the existence of the category would be suspect. Yet I see it is one thing to propose a category by merely putting words together, and another thing to intuit from experience that a form of research is being underutilized, and giving it a tentative label. I consider the original Frayling proposal to be an example of the latter. Frayling encourages a humane, open-minded attitude to a potential mode of research which was, and still remains, partially undefined. Essentially, Frayling warns not to fall into stereotypes when discussing scientists, artists and designers. Artists certainly do not have monopoly on creativity, nor is research a matter of applying recipes mindlessly. The comparison is not necessary, and after avoiding this pitfall the question of integrating research to artistic and practical design activities can really begin. "Autobiography and personal development as communicable knowledge" (Frayling, 1993) are left hanging in the air as possibilities for research, and this is one of the angles explored in my thesis. Just as practice-led research itself, the research through design attitude is not a method in itself, but a broad framing that needs to be specified and explained anew for each different research project. Research by design is offered not as a way to present design works as research outcomes, but a mode of research where more practical and material design activity is an integral part of the research. Besides definitions, it is possible to examine available examples in practice-led research and other ways of telling about design work. As the broadest frame to this research project, practice-led research and practical knowledge will be discussed below in this chapter.

Personal theory

The term *personal theory* is used to further focus the thesis towards a single aspect in the designer's repertoire building process. The repertoire, as discussed above, involves a whole body of experiences and knowing. It is clear that the repertoire, as described by Schön, has subjective elements in it. The term theory is used here figuratively and not to invoke the notion of a scientific theory. The personal theories may also be called guiding philosophies, beliefs or convictions. Bryan Lawson, for instance, describes guiding principles as a set of beliefs about the discipline of design. As designers cultivate their beliefs, they can begin to resemble a theory of design or a coherent philosophy. The content can range from moral beliefs to an understanding of what is technically preferable or optimal. Visions of future, an understanding of the client relation and user's role can also become a matter of the designer's guiding principles. (Lawson, 2006, 159–180.) This and other views will be examined further below. Lawson's definition emphasises a wide world of values. To examine a narrower slice within the broad topic of guiding principles, I will use the term personal theory to indicate a subjective belief about the ways of producing spatial design. Such a belief is part of the designer's repertoire, and this can encompass the whole approach to the task of producing spatial form. Here the interest is in the pre-structuring that is afforded by the use of various tools and concepts that begin to drive or guide the design process. The tool use is not seen as external to a belief about design, but is included within the designer's personal credo. The tools are thus not "just tools" that are there to be picked up, but chosen and learned according to how the person has learned to design.

The later chapters will discuss the different approaches to space that arise from working on the artefacts. The term personal theory reminds that the presented thinking arises from the interpretation of the works. The personal theories are personal preferences about how to devise spatial form. The spatial design task may be envisioned as the manipulation of an abstract volume, an infinite coordinate grid, or as a matter of assembling structural components or arranging furniture. When put into action, these approaches denote different spatial conceptions. This way, the personal theory of space as it relates to design should be seen as distinct from a more general schema about how people understand or perceive space, studied in behavioural psychological or sociological terms. The designer's personal theory about space is instead a pre-structuring device within the design activity. An attempt is made here to be conscious of the author's personal theory and its' development during the project. This is assisted by the fact that each artefact has been built on personal beliefs, which have been subjected to change during the thesis project.

Generative approaches to design

A further concept for giving focus to this work is *generation*, especially as generative moves in design. The artefacts and what they are seen to achieve are examined primarily in this generative role. This means that the examination of simulative and communicative aspects in design tools is left outside this work. Generation in design is here understood to mean the creative options that arise from and are limited by initial choices. Generation in itself is a much used and diverse concept and its meaning will be described more in the following chapters. Jane Darke coined the term primary generator to describe the major guiding insight that drives the design activity (Darke, 1984).

Lawson also discusses the primary generator as one important element in design strategy, a route of approach to the design task. What he sees as important sources for primary generators are the programme (brief), any important external constraints, and the designer's own programme, the guiding principles. (Lawson, 2006, 194–195.) The term generation in design can also imply a position where the designer conceives toolkits for others to produce design outcomes (e.g. Sanders, 2000; Stappers and Sanders, 2003). What seems common in the above uses of the term is the implication of a variety-reduction approach. When beginning a new design task, the designer necessarily directs him- or herself away from mapping an uncomfortably large amount of options. This move can be an arbitrary choice or a self-imposed constraint. For example, the decision to use a geometric organizing device, specific materials or a visual style can be such a move. Many such moves may intermingle during the design formation, and only the reigning concept would be called a primary generator.

Darke's article can be seen as part of the wider critique of the analysis-synthesis model of design that was promoted at the time. Much like Schön observed with the professional practitioners, the designer was found not to apply formal models to design tasks. Rather than analysing the problem meticulously by mapping its relations, the designer may conjecture, or put forward various ideas towards the solution and begin testing them even in absence of hard evidence (Hillier et al, 1984). As Nigel Cross puts it, "Before a proposal can be tested, it has to be originated somehow. The generation of design proposals is therefore the fundamental activity of designers [.]" (Cross, 2007, 33). The primary generator is a defining idea that gives a conceptual backbone to the building of the proposals. The design conjectures are generated from the concept, for example, an idea for a visual identity.

Herbert Simon also described design as a generator-test cycle, where proposals are first generated as educated guesses and only subsequently evaluated. Simon has also suggested that styles of design would originate from different choices of approach, each a preference rather than necessity. For example, the choice of designing a house from inside out instead of outside in, would presumably result in a different style. Whole schools of design could emerge from differences like this. (Simon, 1975.) Donald Schön revisits this same point in his book *The reflective practitioner*, noting that these moves are less obvious in the hands of more masterful designers (Schön, 1991, 103–104). Schön also discussed the way certain words may work as generative metaphors, not only as a way of seeing a thing as something else but influencing the framing and the solution of the problem itself (Ibid., 184–187). Simon's example of designing spaces inside out or outside in will be returned in the chapters, as an illuminating reference point and a good example of a generative choice as both suggestive and a limiting move. The central interest is in how devising space from inside our or outside in, or any similar idiom, becomes played out through some material means. On paper, it could mean drawing the interior requirements first and then defining the façade as an effect of the interior.

Generation is here the major angle for examination when the cases are dissected and explained. It is seen as a concept for outlining and making sense of design processes, where the genesis of the work becomes important. In this dissertation, the generative moves that bring about decisive design outcomes are coupled with tools and tool-like concepts. The three design cases approach generation from these angles, but also have led to and influenced each other. Generation and kin concepts will be discussed in more detail in the artefact case chapters.

Spatial design task

The research project in this thesis originates from studies in furniture and spatial design, but the topics discussed address research within art and design fields generally. The background is mostly relevant for making the author's personal design outlook more transparent to the reader. It has also led toward narrowing down the research task towards questions on space and environmental form. My more formal design competence has been built through first learning the manufacture and design of wooden furniture, and afterwards through a design education in furniture and spatial design. The view of design presented here has been coloured with this background. Design becomes understood from the angle of the practical task of planning the objects, clarifying details through drawings and preliminary models, and generating ideas, shapes and solutions through the exploration of materials and tool capabilities. The ideology in operation here is that no marked difference or hierarchy exists between practical making and theoretical, conceptual thinking. Here, the designer is not just the one who devises and designates ideas beforehand "in the mind" and on paper, to be followed by someone who would manufacture the product. The metaphor of craft in general is part of the author's personal outlook into design. Building the artefacts in this research required drawing, programming and building skills.

The thesis work does not emerge from, nor is directly related to, any specific professional role, such as that of an interior architect. The design work is made for the purposes of a research project, and it revolves around spatial design tasks and skills that are isolated from professional contexts. Practically, the questions of producing images and forms of space are probably more pressing in interior design and architecture, where full scale mock-ups of products are less viable. The topic of design generation is just as relevant to product, service and interaction design, as the fields usually make no commitment to a specific scale of design objects. To a degree, the spatial composing could just as well be related to designing spaces in architectural context as in creating virtual spaces for videogames. However, no claim is made about the direct applicability of the outcomes for the aforementioned practices, as the presented process is a research project.

Research questions

The research project started out with initial research questions, which became refined and transformed over time. At the beginning, the research was motivated by an interest in the possibilities of visual computer tools in design, such as making visualisations that highlight non-tangible and conceptual aspects of space. It seemed that potential was and is being missed in this area. The commercial packages that are presented as essential professional design software appeared to prescribe too fixed and simplistic ways for working, whereas the more flexible and interesting avenues seemed to be only available to programmers. Using my programming skills, I hoped some of these obstacles could be overcome or at least examined from a different perspective.

During the course of the research project, these presumptions have become dissolved. As the objectives have become clarified, the initial assumptions about computer use in design lost their pertinence. Yet in a sense, the project is also about this dissolving. What became of the questions is more relevant than what might be contained in the definite answers to the original questions. As it is difficult for many designers to literally build their own software tools, it ap-

peared more worthwhile to ask how self-built tools could be utilized in a personal design approach. This became the guiding question for my research. I could see the precedents for my work in research that emerges from designing researchers who have demonstrated some elements of tool-building in their work (e.g. Hummels 2000, Sevaldson 2005). I have used the term design tool to denote the variety of objects and rules that have been created in the project. In my understanding of design, the various materials and concepts used in a design process do not have definite roles. In some cases, the line between the tools, mediums and intended outcomes becomes more blurred. The three artefacts are tools in the sense that they are not themselves spatial design outcomes, but designed artefacts that relate to the topic of spaces and design in different ways.

Although computers and digital technology weigh in the chosen approaches, in the end this is not a study about the merits and tradeoffs of using computer tools in design. Nowadays, digital materials and computer software are accepted alongside any other design materials, and a focus limited to such technology might even appear anachronistic. More accurately, the thesis examines the building of spatial design artefacts as a function of a personal belief, much like design objects. In some parts computers have played a larger role in leading the conceptual thinking, as they allow exploration that is not as viable through traditional means. In other parts, the work on the artefact has had more value for clarifying and anchoring the emerging concepts, and the computer work moves to the background. The work is presented as a way to examine and develop design skills as a practice-led design research project. I will discuss throughout the work how the three artefact cases advanced my understanding of a spatial design task.

1.3 Reflective research and practical knowledge

In the following, I will examine further the meaning of personal repertoire development and sharing of knowledge in a practice-led research setting. The topic is examined as a repertoire building process for enhancing one's own skills and understanding. Models for telling about one's design work are provisionally sought from artists' autobiographies and instructive texts. Practice-led research and research through design is presented as a continuation of this tradition. The model in this dissertation is derived from an interpretation of Donald Schön's (1991) reflective research. Schön was worried that some ways of knowing become undervalued in society and academia. Much of this knowing is tacit and difficult to explain, in contrast to the application of formalized knowledge, yet these skills and knowing are central to people's actions in practice. (Schön, 1991, 50–51.) More recent interpreters of Schön's work in design research have picked up and expanded on the theme of design practitioner as a societal actor, building a view of design through examining this role as participant in society. Within this framing, the role of design outcomes, objects, tools and things become addressed from this broader angle, as a web involving constituents and contexts (Binder et al., 2011, 55–60). However, I have examined a different aspect of the topic, focusing on three artefact cases that represent more individual laboratory work. The context of this practice-led project is a doctoral research programme in a university. The skills and tools are examined in relative isolation from the ends and purposes they might be used for. This also means Schön's terminology and conceptualizations have been adapted into a situation where practice is seen as a set of skills, manifested in a series of design cases.

The overall skills I am cultivating take the place of practice. Schön's concern about integrating research with knowing that is harder to describe in explicit terms, remains just as valid.

Designers produce new things and also associated new knowledge. From a technical standpoint, making objects can prove assumptions, such as successful use of new material for a chair. This kind of claim of technical novelty does not generally interest practice-led researchers in art and design context. Artistically oriented designers initiate projects which demonstrate experimental work that addresses theoretical, conceptual or philosophical questions worthy of academic research. In Aalto University School of Arts, Design and Architecture, where the current thesis emerges from, there has been a tradition in combining this kind of questions with creative, material processes. For example, Nithikul Nimkulrat (2009), a textile artist, who worked with paper material in her doctoral thesis project, had no primary interest in the technical properties, but the expressive potential of the paper material. Maarit Mäkelä's (2003) work with clay does not centrally attempt to prove any new method or technique of working with clay, but instead the artistic work offers a way of discussing femininity and representations of gender. I interpret this type of research project as partly a learning process, following Donald Schön's definition of a reflective practice (1991). Research is not just learning a new fact or knowledge about the world, but learning new how-to, skill or extensions to old skills. Distributing this knowledge is reporting the process in a way that assists others in aligning their work with the presented ideas. Possibly the outcome can even provide a model for others to improve their skills and knowing in similar manner.

When attempting to research through design or make practical work and artefacts more central to a thesis, this raises questions about the role of the text. Artist and researcher Kristina Niedderer suggests the challenge results from a communication problem inherent in certain forms of knowledge. Inclusion of experiential and procedural knowledge in a research project is not fundamentally problematic, it is even desirable. Yet presenting tacit knowledge and non-propositional content can be problematic for research, which traditionally has favoured more explicit modes of knowledge. (Niedderer, 2007.) Generally, research output is achieved through writing, and the presence of text appears as an obvious requirement. Yet just a plain explanation or description might be redundant or a poor substitute for the absent, real work. Michael Biggs (2002) offers a rationale for combining text and artefacts as a fully formed research outcome. As the central element in any research is the dissemination of knowledge, this would become problematic with just the artefacts. The outcome objects alone remain too subjective, just as works of art in an exhibition are open to multiple interpretations. For Biggs, including an account of a context completes the artefacts as distributable knowledge. Accompanying artworks with text is not to give the audience an interpretation of the work, but to explain the activities that were relevant for the genesis of the work. (Biggs, 2002.) Alternatively, one can say the researcher's task is to "give a voice to the artefact" through its interpretation (Mäkelä, 2007). Barbara Bolt, coming from the direction of creative artistic research, has suggested that the exegesis[4], the supplied text, ought not to remain at the level of description or explanation, but genuinely complement the presented art works and provide thought that generates new directions within the field. Likewise the works in a research project should not remain in the static role of an object to be explained. The inquiry itself ought to make use of the materiality inherent in the artistic practice. (Bolt, 2005.) The text then would gain some of the qualities usually expected from the works themselves, in that the text becomes a more autonomous effort that produces insight for the readers, stemming from the artistic work rather

[4] One definition given in Oxford English Dictionary for *exegesis* is an "expository discourse".

than describing the process. This position is different to the goal of making tacit or non-propositional knowledge more communicable.

Models for telling about practical work

One central issue in practice-led research is then how one could utilize the difficultly communicated skills and knowing in a way that could contribute to a wider field. The above discussed some options for the overall purpose in writing, ranging from plain description to giving more active roles to the text. There are examples of reporting one's own artistic and design work already prior to any academic, institutionalized design research. Textile artist Nithikul Nimkulrat discusses within her doctoral thesis (2009, 31) whether extant written material from artists, such as Van Gogh's numerous letters, could be considered research contributions. I find this a useful exercise and have collected examples of past texts that serve as candidates for research outcomes. Personal studies and writings on design and art are presented as a counterpoint to those typical of the present day artistic and design degree. A practical reason for building bridges to these accounts is that writings from well-known artists and designers are often more widely available than thesis works on these topics. How well the texts work as a model for sharing knowledge within a field can be debated. Like Nimkulrat, I dismiss the idea that an artist correspondence can be understood as research. However, when examining more borderline examples the question becomes more interesting. In the following, I have chosen to look at published texts from artists that indicate some intent toward disseminating knowledge, even if the texts do not follow a clear research format.

Wassily Kandinsky (1866–1944), the pioneer of abstract painting, wrote extensively about his work. Reminiscences from 1913 (Kandinsky, 1982) is a short text that paints a picture of his artistic career up to that point, how it started out and matured. He recalls childhood memories and early experiences, how places and locations came to have meaning for his art. This occasionally takes quite poetic forms. Italy, he says, is colored by "two memories in black". But it becomes clear that the city of Moscow had a profound meaning to him. Kandinsky retrospectively states that his art is an attempt to achieve the effect that the "fairyland city of art" had on him from since childhood. In the beginning, he sought to replicate this through landscape painting, but later felt this could be better achieved through other means, tending towards abstract painting. Essentially the text is an artistic credo, an overall description of his artistic development and the gradual mastery of the concepts he was working with. The writing combines deeper conceptual understanding about art accompanied with more practical observations. For example, he passes on a tip from his mentor not to work on the most interesting part of the artwork first, but to rigorously commit to routine work. More broadly, he positions his artistic approach as a distancing from the prevalent theories of impressionism, citing artworks and mentors that had the largest effect on him.

This approach may be possible for a well established artist. The career and outcome works are more easily accessible and do not need to be reproduced along the text or discussed in detail. The works can be assumed to be known to the audience, and they are already accepted as influential and significant. Even if the text was not intended as a guide-

line for artists, an attempt can be made to discuss it in these terms. Kandinsky steers clear from technical descriptions of how the works were made and instead offers templates for an artistic attitude. He attempts to describe something about how the seed of an artistic expression is formed rather than exposing how any one painting was made. This way, the text passes on one possible way to frame one's artistic career and a way how works originate. The reader cannot follow it as a method for producing artworks, but can attempt to align his or her own way of working according to the ideas presented by Kandinsky.

Artist and educator Paul Klee's (1879–1940) notebooks (1961) are a collection of lecture notes and short pamphlets. I have come across them as an illustrated, annotated and edited collection. This makes it difficult to see how they originally stood, as the book can give an impression of a more concentrated research effort than it originally was. The first is *Creative credo* (Klee, 1961, 76–80) from 1920, and the second is *Towards a theory of pictorial form*, originally a series of lectures given in the 1920s. The credo is a very short text originally intended to accompany an exhibition, alongside many other artists' texts. In it Klee explains his views on not only how art is made but also how art ought to be viewed. The text starts with the statement that art does not reproduce the visible, but makes visible. Making and viewing art both have a motion in time and are not instantaneous acts. This means that some aspect of the genesis of the work would remain in the outcome. Components, such as lines, ought to produce more complex forms, but should not lose their identity in the process. The credo is somewhat cryptic, but the lecture notes offer more comprehensive insight into Klee's process. Instead of an explicit artistic credo, the text describes the genesis of a picture in detail. The movement of a point on paper is the genesis of a line, the movement of a line is the genesis of plane, all the way up to three-dimensional volumes. This is not just an abstract idea. The pen becomes the device from which the point and line emerge, and a thick brush or a crayon can already produce planes (Klee, 1961, 103). Klee does not explain the genesis of any particular work in his oeuvre, but lays out clearly the way he has approached the drawing surface. Prototypical components for his art appear in the examples. As a description of one's way of drawing, it achieves higher detail and intimacy than a general study about the topic. It remains an example of one approach, connected to a personal credo. Klee is not that concerned about generalizing about alternative ways, but presents his one way as solidly as possible.

When I read these and similar texts many years ago, they did not make much sense to me. It was easy to take a stance that this way of writing had been superseded in present day artistic and design research. Now, having studied further, returning to these texts has opened them up to me. I see resonance with the things I have done myself and the concepts I've acquired from later literature. Just as Bolt suggests that practicing artists may be in a better position to understand questions regarding past art than scholars from outside (Bolt, 2005), there is now something in the presentations that currently meshes with my own project. In slight contrast to Bolt's example, my prior encounters as someone who draws, did not yet produce a feeling of connection to the artists' writings. I feel more affinity to the way that Klee builds seemingly theoretical ideas through almost concrete acts of drawing. In any case, my use of the term design credo relates to Klee. Just as an artistic credo this means a belief base from which all the work emerges. The text Klee titled as a credo is too short and vague to be of much use, but his pedagogical texts are more illuminating. Seeing them as subjective texts makes them more valuable

than dismissing them as failed attempts at objectification. In my interpretation, in his drawing Klee is building up a body of conceptual design work that pertains to his artistic output.

Whether it benefits artists and designers to write much, or researchers to refrain from making art, is an age-old question. The standpoint here is to integrate these approaches. Kandinsky's example shows one to be mindful to one's influences, which may have an early origin. Kandinsky pursued scientific topics early on, to which he credits his capacity towards abstraction, but abandoned them in favour of an artistic career. As he tells in the reminiscences, he had interest toward ethnography and it might be asked how these facts influenced his way of writing and examining his own life and art. I cannot explain my work in a fully autobiographical mode, as I feel the sufficient distance is not yet there. But I also see that to leave discussion of one's own work until at very late in life is to miss the possibility to discuss the earlier stages in close acquaintance, as they happen. It is more prudent to make at least some record of the present condition. Klee's pedagogical texts tells the reader more about the working itself. The attention to detail and examination of one's credo goes beyond the technical act of drawing, supplying both the technique and the rationale. Analysis of a work is the examination of its genesis (Klee, 1961, 99.) My impression is that Klee was not afraid to create work that more readily offers itself up to analysis and backtracking. It is a modernist idea to make work that demonstrates its way of making, and it may be that Klee's analysis of the genesis only succeeds because the works were created in a way that supports an analysis. As a research device in design, this approach could be examined more. I feel that as much as designs are artificial things anyway, it is a valid option to build objects that better support their interpretation.

It could be argued that the texts do not provide any solid research knowledge. All the texts are lacking in transparency when it comes to explaining the motives for making the text, its intended audience and precedent texts. References are lacking, which makes it harder to backtrack the influences and thoughts that are presented. More positively, the texts remain concise and the inclusion of references and theoretical frameworks might have been misleading. The conventional requirements in research can become complex to achieve, and a person who primarily sees himself as an artist might not want to spend time in getting these things correct. A partial rebuttal is that no one text is likely to achieve this alone. Learning from text is always a matter of getting to know a larger whole. After grasping this wider whole the texts begin to make sense. My later reading of design theoretical texts has given me more means to access these artistic texts and they have started to speak to me. There is no definite way to exclude some texts from being useful knowledge, and as the discussion on the validity of practice-led approaches continues, I feel one should not immediately take a side against the past output.

I see practice-based and practice-led research accounts as a continuation in the tradition of telling about one's work. On the first sight the difference is in having more consistency in documenting and use of references. An expressed intent to produce research obligates the researcher to align him- or herself to an existing format. The work is then more clearly positioned along similar efforts, which makes them more comparable. But a practice-led research contribution not simply set an example for others to emulate. The insights offered work on both through the presented artefacts and in the reflective, textual part of the thesis. Nimkulrat's project (2009) involved the artistic project of engaging with paper materials as a continuation of her practice as a textile

artist. Part of her method was to engage in a material she had no previous experience in. This then allows the thesis to recount a meaningful, contained episode in her career. Maarit Mäkelä, researcher and ceramic artist, employed in her thesis (2003) what she termed the retrospective gaze, taking an autoethnographical attitude to her past work. Instead of looking at the technical processes of working with clay, the text opens up the author's artistic identity. Art exhibitions are important milestones within the process, and are brought to foreground in the examination. The creative process is opened up by anchoring it into these milestones.

Apart from the general models that practice-led research has offered, there are recent design research theses that have a focus on computer-based design tools. I have positioned my work alongside *Developing digital design techniques* by Birger Sevaldson from 2005, and Caroline Hummels' *Gestural design tools* (2000). Both of these are examples of research work on computer-based design tools that emerge from design fields. Both researchers examine computer-based design tools from different points of view and also discuss them in a generative role. My work does not build as a direct continuation of these works, but presents another angle that becomes clarified through this available work.

Reporting on reflective thinking

In the chapters that follow, I have opted to report about the done things in a way that highlights the most significant aspects in the making processes. The format in this thesis is mostly derived from practice-led research, with reference to Donald Schön's conceptualisations on practitioner research.

Schön offered concepts intended for dismantling the practitioner's work in a useful and consistent way. I find the concepts of *reflective research, repertoire building* valuable even outside the original envisioned setting of a professional case description. Just as with the professional cases, the reflective research extends beyond a single case. Making a series of different artefacts allows a position where a more overall process can be reflected on and examined further.

The concept of reflection is a basic unit for reporting one's activities. Reflection-in-action and reflection-on-action denote different modes of reflective thought. Reflective thinking occurs both during action and as a retrospective assessment outside the action. Reflection is usually initiated by surprising, troubling or in someway puzzling results in an otherwise ordinary process. This way, not only the post-rationalizations become interesting, but the practitioner must be able to distinguish motives and developments within the actual processes of making. "Reflective research" can be undertaken to enhance the practitioner's reflection-in-action (Schön, 1991, 309). Repertoire building is one possible approach, both as the development of personal skills and the accumulation of shared repertoire: exemplars, tools and methods within the field. Lawyers have their legal cases and architects are familiar with precedents (Ibid, 309–317). In design, precedents are well known and referred to. Yet product images in magazines contribute little to the understanding of design. To go past the superficial, research outcomes have to at the very least describe how and what problems emerged and how they were solved. The thinking that informed choices ought to be made visible when possible. In this way, research can go beyond the immediate practical concern of material utility.

Reflection becomes especially important when reporting the more elusive art and design activity, where aims

rarely map onto clear problem-solving. Stephen Scrivener (2000) differentiates between a problem-solving thesis and a creative-production thesis, both entailing a different set of norms. The problem-solving thesis emphasises an argument that is put forward as a solution to an identified problem. It is concerned with general applicability of the knowledge that can be abstracted from the research. In contrast, a creative-production thesis instead presents a "contribution to human experience". Scrivener, speaking out of experience in guiding and examining thesis works, has put forward ideas about a format the creative-production thesis could take. In a problem-solving thesis, there are usually motives for hiding the more exploratory and practical aspects of problem-framing, even if they in reality were part of the process. (Scrivener, 2000.) I share Scrivener's view that Schön's tendency toward describing the process in scientific terms, i.e. experiment or hypothesis-testing, is less valuable than the overall description on how the creative inquiry advances in practice. When telling about creative-production work, the reporting of reflection-in-action takes centre stage. The partial inadequacy of Schön's terminology is a further reason to search example formats and concepts from neighbouring terrains, as with the above examination on modern artists' writings.

Reflection is not just a label for some meaningful happenstances within the design activity, helping the researcher make sense of activities after the fact. Reflective thinking is something that is actively sought after and stimulated through new activity within the research process. Reflection as a central term benefits from further elaboration. Donald Schön's concept of reflective thinking is partly based on the work of John Dewey, the psychologist and pragmatist philosopher. Dewey presented a definition of reflective thinking in his book *How we think* (1910). Dewey sets reflective thought apart as a consecutive, consequential process, instead

of any series of random thoughts. It is an activity where grounds for belief and its conclusions become considered and weighed. The reflective thought process is commonly initiated by some puzzlement or a problem situation, a felt difficulty, and it aims at a belief. (Dewey, 1910, 2–12.) Reflection as a necessary counterpart to encountering the yet unknown is illuminating, as this unifies all research as an activity similarly motivated. The researcher may encounter problems and puzzling situations, but is also responsible in setting a suitable "challenge" to him or herself to stimulate the reflective thinking process. Especially in art and design contexts, problems are rarely supplied by literature alone. Concerning how the design cases are reported, Dewey's view encourages the separation of the consequential events from plain story-telling. Not all events are worth reporting, and identifying consequential elements within the journey forms the backbone of the on-going reflective process. Thus the three artefacts in this theses are presented as major steps within a process that seeks to address the confusion and curiosity that the research questions represent.

Personal and general theory

The notion of personal theory as it relates to design can be understood in various ways. Design theoretical literature commonly addresses questions of what is design, how can its processes be described and replicated, what is the competence of design in the first place and how does one learn to design. Design research literature aims to describe design in general so as to provide frameworks for understanding as many instances of design as possible. The general the-

ory is here represented by the body of work that begins from the design methods in the 1960s by authors such as Christopher Alexander (1964) and John Christopher Jones (1981). The progression of this movement has been described by Bryan Lawson in *What designers know*? (2004) and *How designers think?* (2006) and by Nigel Cross in *Designerly ways of knowing* (2007). This literature also includes authors from other fields that have been important in building a general understanding on design and its processes, such as Herbert Simon(1996) and Donald Schön (1991).

Personal theories are less discussed in the design literature as they do not appear necessary in forming a general understanding of what design is. Although they are acknowledged, they are less often given centre stage. As already mentioned, Bryan Lawson's examination of guiding principles seems at first sight akin to personal theories. According to Lawson, motivations, set of beliefs, values and attitudes always come into play when design is initiated. Some designers follow them more consciously than others. (Lawson, 2006, 159–180.) The implication seems to be that although the cultivation of guiding principles is seen as important, Lawson sees them more like moral values and ideas about "what is right" that impinge on the design processes. His description of guiding principles gives an impression of something that resides outside the actual designing. Also, the guiding principles appear to be abstract ideas with less regard to materiality. Lawson tells of an architect who is being pragmatic about work, having no conscious philosophy or high ideals. This is presented as an example where the designer does not "find it necessary to strive consciously for some underlying theory to their work" (Lawson, 2006, 163). True, this view may not be a consciously built abstract ideal, but nevertheless the pragmatic standpoint is a clear example of a guiding principle in itself. Thus Lawson presents guiding principles as inner convictions that allow the designer to assert and justify his or her vision in the face of un-evaluable complexity and perhaps audience.

What is sought after is an understanding of personal theory that addresses beliefs, invented rules and attitudes towards materials, and would allow designed tools to express them. Grete Refsum (2007), with recourse to philosophy, shows the historical origins of the division between detached knowledge and the more active knowing in practice. Seeking to answer what theory could mean to design practitioners, she opens up a view to personal theory which is inclusive towards concrete acts of making and skill. She calls attention to two different types of theory, the personal theory and the academic understanding of a theory. Practitioners acquire through work experience their own personal theory, which at the same time becomes proven in practice. Refsum also refers to Schön's notion of retrospective reflection as the means to accumulate a personal knowledge base. Each person carries a totality of practical knowledge. Although personally driven, the knowledge is culturally embedded, and in this way also shared and never entirely subjective. For Refsum, the personal theory is ultimately the overall view on the practical work that the practitioner has. The understanding that a person has of his or her practice is seen as theoretical, it is a personal theory of practice. (Refsum, 2007.) Refsum's formulation of a personal theory is relevant for the definition sought here, even if she does not directly discuss how designer's theory-building could reside in making rules, concepts and tools. These are assumed to be contained in the skills the designer holds.

I propose to advance an idea of personal theory as something that materialises even more directly through designing tools and artefacts. The personal theories are more integrated to the tools and concepts the designer invents and

wields. In the simplest the question is about the status of things like organizing grids or constraining tools as elements in the personal theory. These things are firmly designed objects and allow the conceptual, personal theory to be built by the designer without necessarily resorting to abstract and immaterial thinking. The tools can partially perform the task of a guiding principle, if they are used generatively and not merely as assistive devices. They can even be idiosyncratic and not related to a perceived direct utility. This emphasis towards designed personal theory-objects is what differentiates the present approach from the aforementioned guiding principles and Refsum's overall personal theory. Refsum's intention has not been to elevate any pseudo-theory, but to show the importance of the practitioner's skilled knowledge as a counterpoint to overtly narrow understanding of knowledge. This directly follows Schön's argument that professional practices have their own ways of advancing knowledge relevant to their interests, and do not necessarily derive from an overall general theoretical base. In contrast to Schön, I do not address the personal theory or practical knowledge as embedded into a professional practice as outside academia, and as such do not need to additionally justify the idea of a professional practitioner research. The idea of personal theory is seen as workable whenever design activity takes place, even if it is not embedded in a professional environment. A personal theory is integral to the development of the designer, as it is closer to the practical beliefs from which the designer really derives his or her actions. The belief here does not imply a moral standpoint or an abstract ideal, although this is also possible. Centrally it is a belief about how a design task ought to be approached.

The stance taken here is that peering through past ideas about design provides more rich concepts than would a single, "correct" view into design. It has to be realized that even when theory strives to be more general, it is not exempt from being to some degree subjective, arising from a position or an interest. Earlier design literature sought to promote design as a possible science, with definite methods and rigorous application that guarantees results. This is a view that in the extreme form has now become abandoned. (Gedenryd, 1998). Reading the past, even abandoned theory both from pre-academic times and within the design methods movement, can provide insight even though the intent is no longer to apply them or to use them in prescriptive ways. When read as subjective statements, they may actually be aligned more to the kind of texts and manifestoes the artists produced. As stated, in my chosen approach I do not distinguish a hierarchy between theoretical and the practical, nor do these map over a divide between material and immaterial. Material tools, concepts and personal theories are discussed as potentially valid contributions to the field of design. In this way, the artists writings discussed earlier are also part of the production of knowledge associated with a field.

1.4 The mode of approach

The thesis is an examination of building artefacts as a way to construct a personal theory in design. Three design cases are presented, each discussing a different artefact. I limit the term *artefact* in this thesis to refer to the three central objects that have emerged during this project. The description and analysis of these cases comprises the three central chapters in this thesis. The final chapter will discuss the whole process with hindsight, after the work on the artefacts had ceased. In the following I will summarise them in advance, and explain their significance for the progression of the overall theme of the thesis.

The three artefacts were built with the expectation that design tools, drawing rules and visualisations are also designed objects, and can be examined as such. To build a design tool is to assume things about design, and therefore the artefact remains as a trace of these beliefs and assumptions that guided its creation. These cannot be recovered fully from the artefact itself, but have to be explained. The artefacts also suggest ideas, generating insight and interpretations that are not strictly explanations or translations from one mode of knowing to another. In this role the artefacts also serve as kind of anchors, as any credible writing about them has to be linked to them. I have kept the individual artefact case descriptions as contained as possible, so that each of the individual works would represent a distinct topic for reflection, besides their role as a link in the overall thesis chain. A different angle into personal theory development is opened up through the three artefact building cases, and this angle will be explained in the end of the artefact chapters.

The artefacts itself were made and tested during the years 2006–2010. During that time my theoretical understanding continued to evolve. The building phase mostly preceded any explicit understanding of their meaning. This research has allowed the practical work to lead the research project and the reading of literature. The text is an account of looking back at making the artefacts and the motives and impetus that preceded them. The method involves looking back at available materials that relate to the artefact cases. Besides the artefacts themselves, project diaries, photographs and sketches provided examinable material produced in the period of inspection (2006–2011), with a focus on the latter artefact cases, and in some instances I have included material produced before 2006. The illustrations, figures, drawings and photographs in the thesis work were all produced by the author, and are either selected from archived material or created for the purposes of this manuscript. The material is reviewed in order to see, for example, whether an idea or way of working arose before, during or after the building of each artefact. In all cases it has not been possible to pin an exact date on a drawing which was only later revealed to be relevant. Even then it has been possible to date everything to a quarter or a month of a year. Looking back I have attempted to describe the cases and the consequential activity with them as honestly as possible. As the project has advanced, clearer understanding has arisen about the meaning and status of the artefacts within the research project. The text in the dissertation is the result of this examination.

The chapter format

The three following chapters describe each of the three artefact cases. The chapters share a similar structure, describing the motivation behind each project, the way they came to be built, the subsequent experimentation and the associated literature (Figure 6). Each of the three artefact projects was initiated to direct the ensuing reflection towards an intentional direction. Here the central claim is that the choice of subject matter as tools helps in directing the designer-researcher's reflection toward topics in designing itself and a more heightened recognition of one's personal theory. To this end, each of the artefact cases are analysed in similar manner. An account is given of making the artefact and also its spin-offs. Each artefact case is interpreted in dialogue with the literature it has suggested.

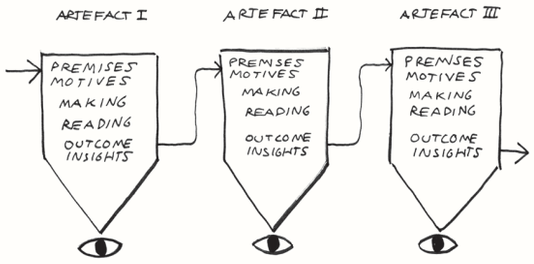


Figure 6

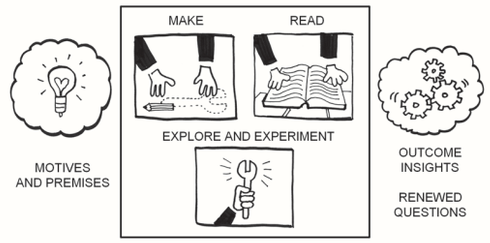
The three chapters describe each of the artefact cases in a similar way. Each chapter text represents a looking back at the premises that guided the tool creation, the making of the tool and the reading of the related literature.

At the end of each of the chapters, there is a discussion on the insights and outcomes that arose as a result of the process after the work had become creatively exhausted. This interpretation following the case description is a view of how the artefact appeared in the aftermath, which has been made in hindsight (Figure 7). In this work I have chosen to examine a development that extends beyond an iteration of a single design case. This is because the single artefact was not sufficient for my purposes, and only through exploring three different angles the thesis topic came to be exhausted. The personal theory becomes illuminated through transitions from one artefact to another.

Although the artefact cases have differences, they are bound thematically and begin to show elements of a broader design credo, that is, provoking reflection on the series as a whole. The multi-directional approach is thus also a characteristic of my way of working, whereas some other researcher might have favoured a journey into a single material or a tool. Including this variety of work gives a realistic view to my way of working where multiple topics alternatively occupy my attention and ideas are developed in parallel. Even if the artefact cases are presented as chronologically following each other, in fact they also overlapped and informed each other.

Figure 7

Each artefact case is discussed as arising from preconceptions and motives. The making and testing of the artefacts is reported, as is the literature prompted by the case. The resulting outcome insights are discussed at the end.



The overarching research object is the personal design theory and its development through the reflection afforded by the tool-building process. The thesis follows how new concepts become acquired during the process. In the retrospective analysis of how the artefacts were built, the repertoire of skills and design moves become also visible. Here the personal theory is also a skilled way of working with materials and tools. The overall outcome of this project is discussed in the final chapter, which collects the views gained in the artefact chapters and provides a "rear view" on the entire project (Figure 8). The development is achieved through the interpretation of the artefacts. When discussing a retrospective consideration of a series of past cases as part of the method, I see the thesis works by researching artists Mäkelä (2003) and Nimkulrat (2009) valuable. The researchers have described how the development of their practical work intertwined with the development of theory. Presenting the artefact work and their reflective analysis together as a cyclical process allows the reader to view something of the process as a whole. In this sense, the thesis works have supplied me with a format from which I have derived my own way of working with this research approach. For my thesis, I have given a structure to the thesis that I intend to support the overall examination of my process.

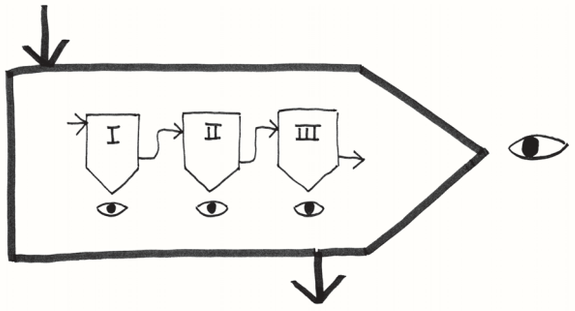


Figure 8

The diagram describes the relation of the final chapter to the artefact chapters. It involves a look back at the whole project as a journey, from which insights can be gathered.

In contrast to the above examples, exhibitions have not been central to the thesis work, and neither is the practical work envisioned as part of an artistic career. Although some material has been publicly exhibited from each case, the exhibitions do not signify meaningful end points to the cases and are not presented for evaluation. Instead, I have accepted that as work around one artefact has exhausted itself, it has become almost naturally abandoned in favour of something else. At this juncture it begins to make sense to look at the activity as something past and completed. Similarly, distinctly new directions arise from the aftermath of the work and it denotes the beginning of another case.

The three artefacts

The following describes the three cases that are examined for the purposes of this dissertation[5]. This will summarize their role in the overall thesis. The first artefact is a computer visualisation, the second is a hand held tool, and the third is a space modelling program. In each case, a design work is initiated as a means to gain an entry point to the topic at hand. This is followed with a literature review which provides a standpoint from which the work becomes examined. For all the cases, this forms an initial step of the reflective cycle.

FIELDS OF VISIBILITY: The first software artefact was originally built for my master thesis but it has been re-interpreted and revaluated for the present research. The computer program calculates view area shapes within a plan drawing, meaning the covered area that would be geometrically visible from a chosen point (Figure 9). This idea was tried out in various ways. One version allows a person to move the

[5] Conference publications have been written related to the three artefacts (Heikkinen 2008; Heikkinen and Mikkonen 2010; Heikkinen 2011a; Heikkinen 2011b). The respective chapters make use of some of the material and images in these papers, but the interpretations offered in this thesis are new.

Figure 9

shape along the plan drawing, and yet another version produces a long exposure of view shapes over a period of time. Michael Benedikt (1979) showed the principle of growing these forms in the context of architecture and urban planning, but this kind of depiction has its roots in James Jerome Gibson's (1986) ecological theory of perception. This theory will be later opened up in the analysis of the artefact.

Building the computer visualisation served as a starting point for the practice-led research process, as it directed attention to the experience of space and perception. It fuelled the initial questions and problem areas in this research project, and as such set the stage for the entire study. The first artefact sets the tone for the later artefacts in that all the works are concerned with immediate spatial experience of physical surroundings. In the first artefact case, the major outcome for considering the emerging personal theory is the idea of a conception of space, and making the conception of space more visible for reflection through building and experimenting with the visualisation. From this initial work arises the question of how this idea can be put forward when designing spaces.

THE COLOUR POINTER: The second artefact (Figure 10) originated from the idea that building a hand held object could illuminate the topic of design tools, much like the first artefact allowed a way in for discussing space. The colour pointer is an arrow-shaped tool that contains a microcontroller and a colour sensor. The tool is used to collect colour readings from the surrounding environment. It either sends the values immediately to software on a laptop computer or stores them internally for later use. The colour collector was used to pick a palette of different colours from various sites to make site descriptions out of colours rather than forms and images.

Figure 10

The tool relates to the way interior designers and restorers have a practical need for collecting colour palettes from existing sites. Yet here the building of the tool was driven by an initial understanding that tools limit or constrain what influences or material the designer picks up from a site. Taking dimensions and photographs is assumed to be universally desirable, and as a provocation I sought an alternative angle. A decision was made to deliberately limit the view towards the site to what the tool imposed. It was only possible to pick colours from surfaces that could be brought within bodily reach. Experimenting with this device in various situations helped me to see the concept for the tool in a clear outline. It appeared that the tool was ultimately not necessary for performing the task, if one is willing to follow the rules the tool entails. Yet at the same time, the concept arose through building the artefact.

From this follows the notion of a personal theory as a driving force for building the tool. At the same time, reflecting on the process transformed my understanding of the ways designers' tools work, and again suggested entry points to design theoretical literature. The building and testing of the hand held tool informed the reading, with a view to how design ideas are born and decided, and how they guide the formation of the outcome. I am then able to identify the strain of design theoretical discussion that I find the work most attuned with, bringing the design-generative approaches to closer view.

Figure 11

THE TILE MODELLER: The third artefact is a computer software tool for creating shapes (Figure 11). The software provides a view into a three-dimensional space made out of tiny blocks. Navigating the space is similar to those offered by many computer and video games. At the same time, the designer can draw a line in this three dimensional space along the three directional main axes of the space. The

premises of the tool are explained as arising from tendencies in my pen-and-paper sketching. Therefore the software results from my interpretation of what is central to a design drawing process, as relates to interior space. This is followed by discussion of the way the tool building again influenced the sketching process, providing an example of a process where the two activities have informed each other. This provides a more elaborated cycle than has been presented in the two previous cases, as the work on the artefact can bring the insight back into the drawing process from which it emerged. This way, building the modeller allows a way to reflect on aspect of design drawing skill.

The artefact building initiated an examination of the literature on sketching and design drawing, and later towards the topic of designer-originated practitioner knowledge on design drawing, evident in perspective method manuals. The presented process is considered as analogous to building a perspective method as an entry point toward learning freehand drawing. The analysis of the methods builds on the perceptual interpretation established in the first artefact case. The perspective methods are examined in terms of what they achieve as generative moves.

The artefacts as tools for reflection

A point about the three artefacts needs to be reiterated before presenting the chapters. This concerns the role of the artefacts and the ensuing insights in the central argument in this thesis. The devised artefacts were built and examined as means for exploring a topic for reflection, and not as novel types of tools or inventions. As described above, the three

central chapters have a similar format: a device is built, the making of and tryouts begin to suggest an angle from which to look at the meaning of the artefact as a contribution to a personal theory building. The personal sensations of discovery are not offered as research findings. How the personal discoveries are arrived at, is of more interest. The discoveries are made possible through making the artefacts in the first place, and subsequently the literature was found to have themes that resonate with the design work. This is one way how the artefacts play out their significance in the longer process of this thesis project. The road to reflection and the accumulation of personal theory is ultimately offered as the interesting outcome in the chapters. What the artefact and the reading of the literature allowed me to summarise, becomes again more distinctly recognized in the literature, and is turned toward further work.

Yet, to suggest that the artefacts merely act as entry points and filters toward literature would be to give them a too shallow role. Building the artefacts and trying them out has made the topics vivid to me, and in describing the three artefacts I attempt to collect and capture the journey I have undertaken. I will also present the exploration of variants and alternative purposes for the artefacts, which often turn out to be abandoned. Both the literature and the variants allow me to examine what made the central artefact tick. The question becomes posed why the abandoned directions were not satisfactory, and this too contributes to the artefacts' role as focal objects for reflecting on my personal theory. Ultimately the cycle of building and reflecting on one artefact becomes complete, after which the work can continue to a new direction. The tools are thus analysed as means to examine how they forward one's reflection and increase the consciousness of a personal design credo. I am concerned with the tacit aspect of imbuing one's ideology in the choice

of tools and putting them into use. The significance of reflection for design is already well described in Schön's description of design as a reflective practice, and the role of the talk-back of the material was already shown to be valuable for the practitioner's mode of thinking (Schön, 1991, 76–79). The topic of building one's own design tools towards reflection presents a less discussed topic. This contribution is more directed towards research fields where the intent has been to utilize design as a vehicle or means for research.

The following chapters describe a process of building tools that are more aligned toward personal preferences and interests. At first, I used the artefact building process is used to develop and examine a conception of space. Ideas about engaging and proposing spatial form are made into artefacts, and the dialogue with the work is expanded to literature which supplies explanatory devices. In the middle chapter, the discussion turns towards the building of tools as a way of advancing one's understanding of generative design moves. The fourth chapter explores the notion of the personal design theory as a more vague conceptual entity that is played out through skilled activity such as drawing. The development of the personal theory is the overall thematic which is examined after each artefact case.

Retinal journeys
Figures 12–17 19–20

Figure 12

A single view shape is derived from a point in a city plan.

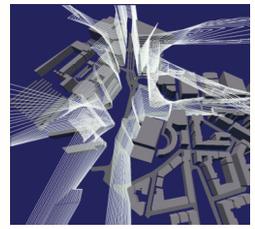


Figure 13

A shape generated by stacking multiple view cones on top of one another, each from a slightly different viewpoint.

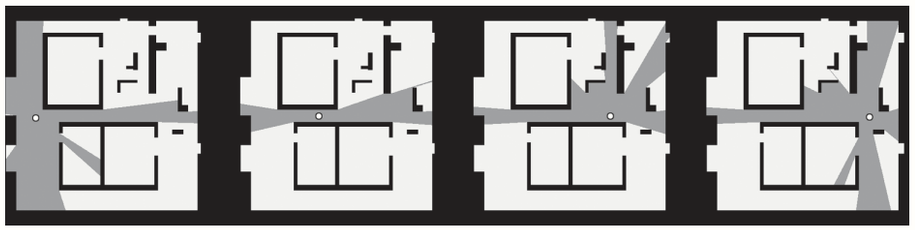


Figure 14

These images show the change in the view shape as the point of origin is moved, showing the potential vistas that open within the chosen path.

Figure 15

Statue in a public space in Helsinki, *East and West*, Harry Kivijärvi 1980. Further away the statue of Mannerheim in front of Kiasma. Looking at and through this statue from a window prompted thinking about visibility and the volume the statue could see. Photograph by author, 2011.

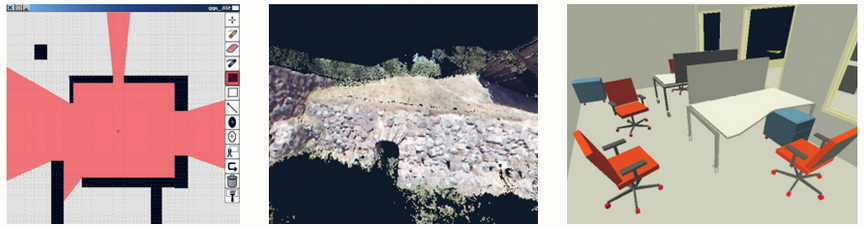


Figure 16

Three abandoned directions. A: A program for combining plan drawing and the view cones. B: Viewer-centred exploration of furniture in interior. C: Exploration of point clouds.

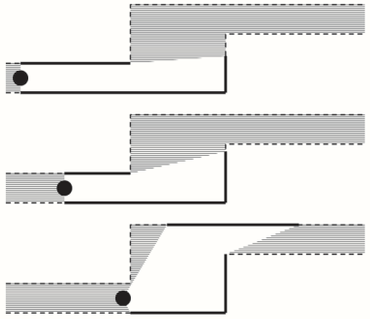


Figure 17

Adaptation of Gibson's illustration for opening up a vista at an occluding edge. (Gibson, 1986, 199)

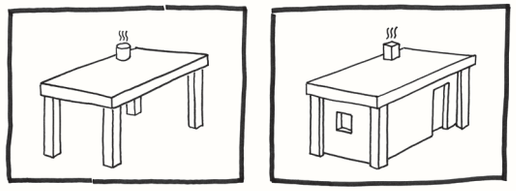


Figure 19

Personal conception of space I: Space as big furniture. Space is seen in terms of its required physical construction.

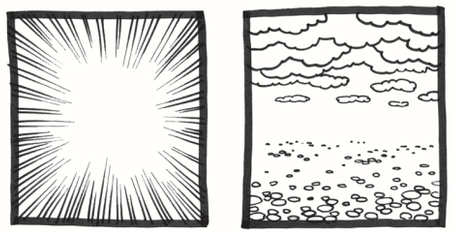


Figure 20

Personal conception of space II: Building the artefact initiated reflection on how space is perceived in motion and what such a framing would mean for design purposes.

2. Retinal journeys: Visualising movement through space

The first artefact case is instrumental in setting up the research project and its direction. A computer visualisation about experiencing space in motion prompts questions about its meaning, and initiates the related reading into the topic. The visualization frames space in terms of visibility and perception, setting ground for the further artefacts.

"Computer imaging tends to flatten our magnificent, multi-sensory, simultaneous and synchronic capacities of imagination by turning the design process into a passive visual manipulation, a retinal journey."

–Juhani Pallasmaa, *Eyes of the skin* (1996, 12.)

2.1 Background and motivations

The first artefact is a visualisation of a person's changing view when moving through space. This is achieved by drawing series of view shapes along a path in a plan drawing. This illustrates the way views open and close as a person moves through cityscape. Looking at the form as a visualisation of movement through space prompted me to find literature on perception and experience of space. The question arose how the perception in motion becomes grasped in design work. I was driven to explicate my understanding of motion in perception, which led to an interpretation of the artefact.

This original puzzlement and problem situation provoked this entire doctoral thesis project. I now know, in hindsight, that what I had struggled to do was a kind of research through design, where making, thinking, and reading are

intertwined and inform each other. This process begun in earnest only after the visualisation was made. The shapes suggested more than just abstract form generation, and I was not satisfied to use it for this purpose. The doctoral thesis project follows a similar approach. In this process, a way of working begins to unfold through building artefacts, and looking back at this process reveals more than reflection on a single object would have allowed. Each of the design tool artefact cases informed the next one, but also the concepts that arose in the wake of each case could be used to read the other tools in a different light.

The first artefact is a visualisation (Figure 12 and Figure 13), whereas the later two artefacts explore spatial design tools in different ways. The work around the first artefact is examined in order to explain the motive for the thesis and the work on the subsequent artefacts. The first artefact case is included here as the starting point for the period covered in this thesis, during which a conscious effort was made to explore questions about artefacts and tools in designing spatial form. This doctoral research project is a continuation of my past work, but only this first artefact has a clear origin in prior work. The visualization was initially made for a master thesis project (partially described in Heikkinen, 2008). In this doctoral dissertation, the artefact is re-interpreted. What results is an understanding that an artefact is not a single object or software piece, but the method of producing one mobile shape from a plan. The motion of the view point origin is demonstrated as a series of pictures in Figure 14. Another version builds an overall shape through accumulating a long exposure of multiple shapes. The resulting shape can then be looked as a three-dimensional object (Figure 13). This basic artefact idea becomes explored through various prototypical software pieces.

Figure 12
Figure 13
Figure 14

This chapter will explain the way the design project came to be and how the idea and execution emerged. The work prompted reading of literature, which will be discussed alongside with the implications and influences that emerge from that direction. The end part describes how the visualization frames space for the designer. The motive for doing the work then goes beyond the initial impetus of just making something visually interesting and the research questions are then further articulated. The work and the outcomes are examined in terms of the goals that have emerged during the process as part of my doctoral dissertation.

Precedent work

Although designers and architects have used view cones and like shapes on plans and sketches for a long time, a more decided effort to examine these shapes for architecture was initiated by Michael Benedikt (1979). Benedikt's intent was to provide a new general way for describing architectural space in a more quantifiable way. He would link the shapes, which he called isovists, to human behaviour in environment as relates to visibility and view control, privacy and crime incidence. Benedikt also built time-lapse sculptures by stacking cardboard shapes, and inventively used lamps to produce moveable shapes in a physical model environment. Benedikt connected the shapes to psychologist James Gibson's ecological optics, and incidentally, to architectural theorist Sigfried Giedion's proposal on three major historical space conceptions. (Benedikt, 1979.) Gibson had used view shapes in an illustration to show in plan the opening and closing of a vista as a person traverses a corner (Gibson, 1986, 199). Unlike Benedikt, Gibson did not discuss the application of these

shapes, and for him the shapes remain an illustrative device.

The studies using these shapes seem to have mostly been quantitative, with emphasis on analysis rather than form production. One form of analysis stems from combining all possible views in a given plan, resulting in a total picture of gradual differences in visibility in the space, a technique already presented by Benedikt. Later developments have emphasised the field analysis and not so much the individual shapes. Turner et al. (2001) provides an example that relies on a previous analysis and observational data collected of Tate gallery at Millbank, London, by Hillier et al. (1996). The art gallery floor plan was processed with the view geometry, resulting in a visibility map, highlighting the more visible locations. This map was compared with maps built out of actual observations, such as traces of visitor movement and room occupancy levels during a day. Comparing the observation maps side to side visually with the visibility analysis shows there is a degree of similarity between the analysis and the collected observations. (Turner et al. 2001.) Presumably such an analysis could be used as a predictive tool in a planning process.

There has been less discussion of these view shapes as possible design material. It is almost exclusively a theoretical architectural research topic, belonging to the domain of space syntax. The space syntax research seeks quantifiable approaches to spatial analysis for architecture, the major work being Bill Hillier's *Space is the machine* (1996). This is not the route followed here, nor I am following the terminology used in space syntax or by Benedikt. So, instead of isovists I will talk of view shapes, and when describing the time-space visualization I will not use the term "Minkowski model". The artefact here is not examined for purposes of analysing some existing space, but as a way of examining the process of grasping space. When taking a design approach to these shapes, my starting point was to understand whether and how the visual shapes themselves would work as design material in a direct way. Furthermore, the design angle was that of a central interest towards making new space rather than analysis of existing spaces. I sought to bring the shapes and their interpretation to become a part of the designer's reflective talk-back with the material. (Schön, 1991, 79.) In this sense, Benedikt's original model-building and lamp experimentation seems to bring the idea closer to material experimentation and back-talk, whereas the quantitative studies would perhaps support the designer in a more analytical or retrospective mode. In my approach, I have chosen to pursue the exploration of the shapes through making computer programs

2.2 Making the visualisation

When describing the building of the first artefact, the focus is on the significant conceptual steps and junctures during the process. These are seen as the major elements in the ongoing reflective design process during the case. The intent is to demonstrate the way the conscious idea for the artefact emerged from quite simple considerations, and only subsequently prompted questions about its significance to spatial experience and as a basis for further design work. The more technical aspects of programming the artefact are excluded from the description, as making the program was a straightforward execution of the first idea[6].

[6] The visualisation was written in the C programming language, making use of OpenGL graphics library.

Original impetus

The artefact is a visualisation of person's experience of viewing space in motion. The shape is derived by stacking view cone shapes on top of each other. The ensuing shape can then be viewed from different angles as an on-screen object. The initial seed for the work was an experience of looking at a statue in a public space. (Figure 15) In the middle of a small area, seen through a window, it prompted reflection of visibility in that situation. In these surroundings, I thought of a statue as something defined by its being seen. This prompted the question, what would the statue "see", and what would the shape of the area be like? At this point the idea was created to satisfy a coursework assignment in spatial design, but the project began to have life of its own outside and after the course[7]. Eventually the work became the basis for the master thesis.

Figure 15

During the work I did not seek background information about the statue and its origins, so these did not weigh as inspiration. Instead, the experience prompted me to draw shapes of visibility on a plan drawing. It is possible that the physical shape and the narrow slit in the statue partly suggested the turn toward visibility (again, see Figure 15). Trying the drawings out a few times I found the shapes themselves to have attractive geometry. Later, this process was made into a computer program which produces these shapes very quickly. The shape could be shown in motion both as an animation (Figure 14) and as a time-exposure shape. The time-lapse or superimposition technique was already well known to me and it struck as an obvious choice. The ease of working on the shapes with a computer provoked further exploration, as some outputs seemed more interesting than others, and trying them all out with a pen and paper would have been laborious.

[7] This assignment was part of a longer course given around 2003 at the spatial design department in University of Art and Design Helsinki. The task was to map a non-physical element of space. This was an example of a more abstract assignment in the spatial design department. I have left out the description of the course material, which mostly involved building the shapes physically.

Emerging research questions

At the beginning, the design task had no theoretical aspect to it, in the sense that it was not an attempt to illustrate an existing idea in literature. The work was an exercise in form generation with computer software. The ideas and techniques followed each other until I had the complete visualisation at my hands. At the same time the figures seemed to say something about the experience of motion, and I wanted to be able to understand and explain why this was so. The visualisation would help extend understanding space as in motion. Especially it would emphasise the role of interior space, as opposed to an overview provided by plans and sections. The exploration was guided toward computer software as moving the shape point of origin on screen seemed more promising than drawing the shapes on a paper. Also, the power that computer afforded in producing the more complex shapes suggested that this angle ought to be studied.

This way, exploring the shapes was driven by various points of interest, not all related to explicating perceptual theory and experience of motion. Perspective view points of origin are denoted in plan views with small triangular cones, and ergonomics illustrations also make use of visibility triangles. The visibility between locations can be shown by simply drawing lines between points in a plan, or outlining the area that can be seen from one point. All these are part of the known vocabulary of design drawings. The aim in the beginning was that the view shapes might work inside this convention of plan drawing, extending the vocabulary or making it more vivid. These provisional directions served as the motivation for continuing the work on the artefact and the associated literature, and served as provisional research questions during the first artefact stage. Making the motion sculpture encouraged reading of literature related to perception and experience, most importantly Gibson's perceptual theory (1986), as will be discussed below.

The field of visibility exhibition piece

The visualisation software was built multiple times. Each implemented a different take on the issue, an attempt to create software that would expand the idea further. The most definite version was an exhibition piece, which shows the progression from a single view shape to the construction of the three-dimensional sculptures as an animation. The display was rear-projected onto an opening in the exhibition wall. This exhibition display also allowed the onlookers to define the start and end points for the shape creation in a given map, and view it from different directions. The program played the animation automatically, and if a person picked up a gamepad the program would behave differently. The shapes could be manipulated and viewed from different directions using the game-like controls. This part of the work was not very successful, as the controls were still problematic for visitors. Yet this stage was significant in that the exhibition assignment suggested a different approach to how the software would be made. It was also the first attempt to make the visualisation public to an audience.

The work for the exhibition piece served as groundwork for the further artefacts. As the exhibition piece had required more serious work in making the idea presentable, effort was spent in making the software re-usable for different purposes in the future. The earlier work on the topic had resulted in quick and sketchy prototypes that could not be easily expanded. Making the visualisation multiple times in different ways resulted in practical experience about the differences in these approaches. The retakes were mostly driven by the will to have a more flexible, malleable version of the software, and the outcomes became evaluated according to this goal. For example, the spatial plan could be constructed from geometric lines or it would be possible to simply use a bitmap drawing. Working with bitmap pixels was much simpler than geometrical lines, which produced difficulties as I am not that mathematically minded. The single largest effort went into finding out how to calculate intersections of geometrical lines in a way that would be practicable in the software. This difficulty was overcome, but the work left an impression that line geometries easily result in unforeseeable difficulties and it is less easy to build further on them. This had consequence for the choice of modelling matter for the third artefact, as I wanted to avoid the more complex line geometries in the future. The primary interest was not in the mathematics of the shapes but their appearance. In further work, I would opt for a visually credible rather than geometrically precise solution.

Significant outtakes

After this work around the visualisation was finished, I was left with various software pieces that could be further developed or brought to new directions. These represent the first exploratory moves within the doctoral research project. Three directions were pursued so far as to have a material existence. In my interpretation of the practice-led research process, I have included depictions of this early work, even if they do not directly represent the direction the conceptual thinking and theories eventually took. As these three have had consequence, I have chosen to describe them as stages within the reflective research process. Unfinished trajectories have been important when deciding what would become the more definite artefacts.

Figure 16 Each of these outtakes was a contender for becoming a central artefact case, but was not considered worthwhile for one reason or another. Images from the outtakes are col-

lected in the Figure 16. Making these helped me appreciate each respective direction, although they were assessed as not worth examining further. One might consider them as probing sketches for new ideas after the original visualization seemingly came to a dead end. At later stages the research focus was not allowed to slip towards these topics, because they were already known to be problematic or uninteresting. Yet, each did provide insight or experience that turned out to be useful at a later stage. Furthermore, each exploratory direction is also a deliberate attempt to understand an already established way of modelling space, without necessarily going deeper into the related technical literature, helping accumulate a practical understanding on the directions.

After making the visualisation in the exhibition, I wanted to find ways to use the shapes in design. Figure 16A depicts a floor plan drawing program, where the view cone is present at the same time as the plan is being drawn. This was an entirely new piece that was not based on line geometries but on a pixel bitmap. As mentioned, I wanted to avoid the trouble that can emerge from working with line geometry. It was simpler to work with bitmap images and the idea could be put to work very rapidly. Picking different tools from a set of icons, a person can draw walls and doorways with freehand, boxes or ellipses as in any paint program. At the same time the view shape, which is constantly present, can be moved around the plan. Adding openings to the walls shows instant effects on the view cone shape. A preliminary test was made with one student, who had a visibility-related issue in her spatial design coursework. Although the program could show aspects of visibility that otherwise might have required model-building, the drawing portion of the program turned out to be more problematic. This added to my growing misgivings about having to work with plan drawings, and the software was discarded. Yet the issues related to drawing and

the positive experience with working on pixel graphics instead of line geometries provided premises for the third artefact, described in chapter 4.

Figure 16B shows software for moving furniture in a three-dimensional visualisation. This was already a break away from the visibility shapes and plan drawings. Instead a perspective view is given conventionally. The work was built directly over the exhibition software, and the goal was to achieve motion and fluidity of fast video games. The models for the moveable objects were made to depict the furniture in the immediate vicinity in the researcher's room I was working in. These components could then be moved, rotated and multiplied around the modelled interior environment. Although this type of software is generally available, I thought it would be possible to understand the angle better by building one myself, and also to contrast the experience with the view cone visualization. Here the categories and typologies of objects are strictly defined by the program structure. This conflicted with the idea of free continuous space and the unconventional visualisation present in the original artefact. Nothing new arose directly from this exploration, although again certain aspects guided decisions at a later stage in the research. In practice, the game-like movement around the environment was re-used in the third artefact. More significantly, the topic of a computer program as determining the design options was now introduced into the research in a very clear manner. As the program could not import furniture models except the ones I had painstakingly created, the questions of fixity prompted by computer programs became very tangible.

Exploration of point clouds as possible model material became the third variant, a direction depicted in Figure 16C. Point clouds are models that are made from vast amounts of points, each with three-dimensional coordinates and colour

information. So a surface becomes defined by point densities which gives an impression of solidity, and in principle, point cloud modelling offers the greatest freedom for form definition. Laser scanning is one means for making point cloud models out of real environments. Point cloud models can be produced by the computer too, but the possibility of laser scanned objects were fascinating because they represent the high end of realism when it comes to depicting existing locations. This was really a continuation of the previous theme, and was also based on the same exhibition software. This program was intended to help me explore the idea of selective hierarchy that had governed the interior explorer from a different angle. Here the sheer technical cumbersomeness proved fatal for the chosen direction. Although the point cloud objects could be displayed, it was too slow for any effective manipulation. Also the technical difficulty of the task and lack of a real motive weighed against choosing this direction, as realistic depiction seemed a conceptual dead end. In this way the exploratory momentum stemming from the exhibition piece began to be exhausted. Yet the notion of using a single, homogeneous model material became again current in the third artefact case.

These explorations were presented here as having dead ends, but this is a bit too simplistic interpretation. At a later time, it became possible to understand the ways tools allow ways in into concepts, but this view had not matured at this stage. As already mentioned, the subsequent artefacts did benefit from the groundwork made during this phase. The third design tool artefact, discussed in chapter 4, is based on the same software platform, benefitting from the background work done at this stage. The third design tool artefact articulates more fully the ideas that were here in gestation. At this point I was starting to question to what extent the original concept driving the visualization process could be made into a productive tool. Besides, visibility cones and view shapes can be explored using existing software and even in drawings. What remained was the idea that the artefact could relate to an idea of space. The fact that I had nevertheless wanted to do my own software came under scrutiny. It seemed more appropriate to think of the outcome as a result of a more personal process, and the explorations likewise as appendages in that process. The artefact as a visualisation had come to a creative dead end, and it was apparent that another angle was required, and indeed started to present itself. Apart from the practical learning around the artefact and the modelling experiments, this personal outlook was carried over to the later work.

2.3 Readings and literature

After working on the artefact, I collected literature about generative computational approaches and spatial perception. Firstly, the reading was directed towards mechanical generation of form in architecture and design, such as the use of combinatory rules and permutations. The topics are not limited to computers, and special emphasis is given to concepts that could be exploited outside the narrower context of software algorithmic generation. One purpose is to show how the origin for the concept of generation as it appears in this work has its beginning in this literature. Algorithmic generation was the way into the broader topic of design generation, one of the central themes within the doctoral thesis. Further chapters will discuss generation as a more design theoretical issue, concentrating on the choice of

a generative principle. The other direction was literature on perception of space in motion, relating to the intended content of the visualization. The connection between the literature and the artefact will also be discussed below. In the first artefact case, the literature does not form the background that informed the design case; on the contrary, the purpose was to find meaningful explanations for the visualisation.

Computational and rule-based generation

In the following the generative principle is discussed from a computational architecture point of view, to examine the origins of the term and its use. The earlier computational approaches to this topic sought to explore possibilities for computers to design intelligently, whereas the later discussion has examined how algorithmic generation is afforded to a person designing with more direct tools and mediums. The architect William Mitchell discussed generative systems in *Computer aided design* (1977), drawing on many examples from the earlier work. Mitchell defines a computational generative system as a principle which automatically produces varieties of outcome, building plans being at that time a common topic of study. The computer is largely responsible for producing the outcomes, whereas the programmer sets the rules by writing the software or giving input parameters. A generative system does not usually make the actual objects, but models, drawings or numeric data. With this emphasis, Mitchell wanted to underline the insight that is gained from an indirect approach rather than the convenience of automatic generation. Although the works Mitchell discusses focus on numerical, topological and verbal outcomes rather than new physical objects, he noted that a potter working at a wheel could be an example of a kind of a generative system. (Mitchell, 1977, 38.) In relation to what Mitchell calls symbolic representations, the prehistory of computational generation is traced back to Aristotle's *Politics* (Book IV, Part IV). Aristotle discussed the multitude possible forms of governance, and suggested as an analogy that potential animals could be produced from combining the necessary components. (Mitchell, 1977, 38)

Early on, computational approaches to design meant putting evaluative capacity directly into the software. Only useful and good outcomes are presented to the designer as potential solutions. Generating massive amounts of potential outcomes is rarely desirable in itself. Going back to the example of combining components to imagine new animals, some components would always be necessary for living animals, and it would make sense to only explore these possibilities. The simplest ways to limit the automatic production of building plan drawings is through introducing room adjacency, size and volume requirements. This kind of explicit coding of an evaluative capacity into a program is not a part of the generative approaches discussed here. Instead, the approach is closer to the potter's wheel analogy, where the decision on the success or failure of the outcomes is judged by the author viewing the outcomes. Also, deciding on an organizing principle (such as implied by the potter's wheel) is to make assumptions about its usefulness towards these ends, even if this is not done explicitly. The selection is made according to a motive for filtering out directions and outcomes, and the choice of a tool is rarely random but motivated. A perspective method on paper organizes space into an orthogonal grid, but is not used just because it makes the

drawing lines more manageable. The past tradition in using perspective methods or plan drawing has helped prove its usefulness in practice, and thus its continued adoption for design can be justified. Orthogonal organisation also suggests buildable form and in a way a rudimentary building code becomes imposed, in addition to the different expressions that can be explored with it.

Later discussion in computer's role in design and architecture has been framed increasingly in these terms. Malcolm McCullough, in his book *Abstracting Craft* (1998), introduces the concept of leverage to describe the power of computer: setting up the computer requires time investments, but afterwards it can provide vast potentialities of variety with ease. The history of computation is presented as an accumulation of ever higher level languages and abstractions for achieving leverage. (McCullough, 1998, 96–98) To gain benefits and novelty that is not clearly achievable through traditional means, one should explore this leverage that the computer affords. Algorithmic generation is one central way of exploiting this leverage in digitalized sculptures, paintings or music. This relies on identifying or devising underlying formalisms that work within these mediums, such as the role of notation has in relation to the played music. As computer allows different kinds of discrete notation for mediums such as sculpture or buildings to be manipulated directly, possibility for a *craft* emerges where the object crafted is not necessarily the outcome form or melody, but their underlying root. (McCullough, 1998, 98–102.)

In modern times, formal and computational ideas about space have entered into architectural design as shape grammars and taxonomies of principal geometries. One notion is that physical form or space could have its own language-like structure. Composition of space would be akin to mastering the grammar. The shape grammar thinking of Stiny and

Gips (1971) suggested that spatial form in paintings and sculptures could be constructed out of language-like elements, demonstrating how a parsimonious sequence of rules produces outcome paintings by recursion of the original shape. The rules would be the generative specification for that class of outcomes. As mentioned by McCullough (1998, 95), the generative grammar idea originated from the writings of the linguist and philosopher Noam Chomsky (1957), who posited that the grammars of language in use would have an underlying, general grammar, a source for recombining and developing new expressions for use. Chomsky's writings appear to be the major influence and the origin point for the use of the term generation as it has become understood within the fields of computational architecture. I see that generation since then, especially in design discussion, has started to have a life of its' own as an everyday language term. Not all uses refer to structure, and neither is there a commitment to follow the original definition. The purpose here is not to reveal underlying structures or study them in their own right, but to wield the concept of generation from the viewpoint of designer's activity.

Closer to the approach at hand, Birger Sevaldson has examined generative techniques in his thesis *Developing digital design techniques* (2005). Generative techniques are central to the approaches he describes, but the focus is not on producing alternate outcome proposals, but a possibility to "break the schemata and to bring the process slightly out of the cognitive control of the designer." (Sevaldson, 2005, 178). For example, animations, time-lapse and superimposition are examples of operations that a computer can effect on different source materials. The activities extend to the more complex mapping of forces through relational models and particle systems, which become visualized on the screen or

are in themselves made into abstract physical sculptures for further manipulation. Instead of seeing digital techniques as replacing the designer's tasks, he states that losing control can be made a central aspect of a creative process, and that this loss of control can be "strategized" with computers. (Sevaldson, 2005, 348–349) The designer exploits the emergence of new visual material that could not have been predicted beforehand, or would have been difficult to produce by tracing with pen or sculpting material.

Diagrammatic approaches

The dynamic generative diagrams that Sevaldson has used are related to a topic in architectural theory. The notion of diagram, when understood as an architectural-theoretical term, is little discussed within design research literature. The present research does not make extensive connections to the thinking behind diagrams, but it is notable for the generative approach and later developments in computational generation. The diagram in architecture could be called an abstract visual entity removed from the intended outcome, yet guiding the outcome. The diagram is not limited to sketches, such as bubble diagrams or mind maps that are refined into product or building specifications. The architect and theorist Peter Eisenman gives an initial definition: "Generically, a diagram is a graphic shorthand [...] While it explains relationships in an architectural object, it is not isomorphic to it." (Eisenman, 1999) Stan Allen describes them as abstract machines which do not resemble the outcome. The diagram does not imprint itself on the finished work either. To embrace diagrams is instead to detach oneself from thinking the outcome in process-resultant terms. (Allen, 1998) The diagram is intermediary material in the design process, and not a symbolic map. In this sense the diagramming discussion seeks to be at odds with the more common understanding of generation, where the outcomes are more or less understood as at least schemata for potential outcomes. Manuel De Landa (2000) has opened the broader significance of the diagram discussion within applied sciences. The role of the diagram as a simple illustration of the problem definition becomes questioned when contrasted to morphogenesis, the capability of matter as an active material agent to seek out solutions for itself:

"The DNA that governs the process does not contain, as was once believed, a blueprint for the generation of the final form of the organism. [...] The modern understanding of the process pictures genes as teasing form out of an active matter, that is, the function of genes and their products is now seen to be merely constraining and channelling a variety of material processes, occurring in that far-from-equilibrium, diagrammatic zone in which form emerges spontaneously." (De Landa, 2000).

De Landa concludes by proposing that true thinking consists of problem-posing rather than problem solving (De Landa, 2000). Posing the problems skilfully, apparently through correct diagramming, the solutions would then emerge automatically. It is clear that this kind of diagram tries to go beyond the conventional means of abstracting or schematising aspects in a design brief.

I have presented diagrams as a practical entity as much as can be done without expanding the discussion towards the philosophical underpinnings that colour the discussion. Probing this would steer the discussion outside the scope of this thesis. I interpret the diagramming angle as an attempt to explore the virtues of the architect's condition of being distanced from the outcome material. In the diagram-

ming discussion, this activity has become a medium in itself and its capabilities are explored further by architects and designers. For the most part I reject the diagrammatic angle, and instead align my design tools towards the more directly generative. I see the decided detachment of the designer troublesome for my approach, and even somewhat anti-design. The broader philosophical discussions touch very lightly on the topic of how the diagrams are actually put to work. Although it is clear that the diagrams are not intended as nor associated with design methods, this should not prevent from describing insightful uses in retrospect. Looking at research that incorporates actual work, I consider Sevaldson's work on dynamic diagramming techniques as relevant to designers. It covers more accessible ground by integrating diagrams to visual thinking and gives examples of work that puts the ideas into effect. The dialogue with the material comes into clearer focus.

Spatial perception and design

The second set of readings following the design work relates to what the visualization attempts to depict, to further the artefact's interpretation. The intent has been to present the artefact as a visualization of space through movement. The readings stemmed from the idea that the stacked shapes could act as a visualisation of this concept and not just abstract sculptural form. With this artefact case, the literature search consists of connecting an already done design to theoretical ideas and concepts. A reading of James Gibson's ecological theory of perception (1986) proved to be most helpful. I was eventually driven to it by similarities between

Figure 17

the computer visualization and some of the illustrations Gibson had used (Figure 17). In design fields, Gibson is most famously known for the concept of affordances, brought into industrial design discussions by the psychologist Donald Norman to explain intuitive qualities in product design (Norman, 1988). Here I give emphasis to another part of the perceptual system, namely the experience of space in motion. In the present discussion, affordances are a component of the theory of ecological optics, meant to explain elements of perception, and not a means to devise intuitive objects or environments. To perceive space is to perceive directly its affordances, i.e. how it could be traversed. In Gibson's view, the primal understanding of space is not fundamentally about deciphering signs or appearances. People are simply aware of the surrounding environmental layout and its possibilities for motion. Active motion is central to perception, and any ideas about perception that build on notions about single images or series of retinal images are bound to be incomplete. The basic awareness of the surrounding layout and objects is straightforward, and only through concentrating on anomalous situations they begin to appear ambiguous. Even if a dinner plate may appear from a fixed angle to be elliptical, the shape is in normal conditions grasped to be round. This ability is so forceful, that when viewing a photograph, these ambiguities do not really hinder understanding the spatial layout of what is depicted.

Philosopher Alva Noë (2004) has presented what he calls an enactive approach to perception. Broadly taken, it has shared elements with Gibson's psychological theory, but from an angle that gives even more emphasis to the perceiver's active role. Like Gibson, Noë rejects the still too common idea that perception is built from series of retinal images deciphered by the brain. Perception ought to be taken as action, not reception. For Noë touch, and not seeing, should

be the paradigm for all perceptual modalities. In the enactive approach, both vision and touch are undergirded by an understanding of space that at the higher level of abstraction is similar. The senses are not distinct channels, but modalities of this same skill, the practical mastery of the sensorimotor profiles of object features and environment. (Noë, 2004.) The similarity in seeing and touch is in that the whole of environmental detail is not received all at once, but through the shifting attention and movement of the person. It is better to say that the perceiver has access to the detail and content available in the environment (Noë, 2004, 57). That which is not directly seen, is still virtually perceived, such as the backsides or partially occluded objects (Noë, 2004, 63). Importantly, understanding the layout of the object is not construed mechanically by moving around it, but by knowing implicitly that the movement would reveal the layout in body motion. This relates to Gibson's concept of the invariant (Gibson, 1986, 73). The invariant structure of an object's appearance is that which remains unchanged through all potential viewpoints. A round table in no case appears as a square. The way a dinner plate appears elliptical from an angle is invariant in perception. Knowing objects and space is having knowledge about their invariant structure in perception, and after the structure has been learned, motion is not strictly needed to access this knowledge. Hence photographs for the most part present object shapes unambiguously, even if physical motion around the presented objects is impossible. Insightfully Noë adds that the plate is not perceived to be round despite its elliptical appearance, but that the elliptical appearance from a point of view is just the way the roundness becomes assessed from that one point of view. Similarly, the way trees "appear" different sized from different distances, is really the way the sizes of the trees become assessed in the first place. (Noë 2004, 78–79.) Thus, the way

objects appear from an angle is intrinsic to how they appear at all. To reiterate: the virtual perception of the backsides of an object is not gained by accumulating multiple viewpoints of the object, but already by implicitly knowing that shifting the eye position the backsides would come into view.

Coming back to the artefact visualization, it is possible to now consider whether it would summarize any aspects of Gibson's and Noë's explanation of spatial perception. Initially it has to be said that if the visualisation were taken as a direct representation of a viewing experience, then certainly the visualisation suggests a coherence and homogeneity of visual perception that is not really supported in the perceptual theory. Especially Noë opposes the idea that there would be a mental equivalent to having a whole scene available at once in perception. Any perceptual experience would be directed by intent and circumstances, and presenting these experiences on a time-axis as equivalent to each other would be a false depiction. However, what the visualization aims at is not to depict the experience of seeing, which would be far more simple and effective to convey through a perspective animation. Instead, what is sought by juxtaposing the visualization with the perceptual theory is an affinity with the underlying principle or structure of the perceptual experience in motion. According to these authors, the layout of space is accessed through actively viewing a portion of it, implicitly understanding the unseen portions. The edge and surface invariants, and in turn, the affordances become the perceptual content for vision. To perceive space is to perceive the layout and means of how to traverse it. I suggest that this much the artefact can outline, giving a distinct impression of this process as the point traverses the plan. The path-shape as a whole has some affinity to the idea of Gibson's invariants or the sensorimotor profile presented by Noë. The shape collects together a path and makes a dis-

tinction between areas that are constantly under view, those which are temporarily under view and those areas that are not viewed at all along the chosen path. Even then the purpose has not been to illustrate either the sensorimotor profile or the invariant. Looking at the visualization shape does not intuitively reveal things about the space it is derived from. If it were possible to visualize a person's sensorimotor knowledge of an object, it probably would not resemble the object, at least not in the way a map resembles the space it depicts.

What does it do to dwell so much on the fundamental nature of perception? After all, as Noë points out, it is not really that in everyday experience people would be committed to false ideas about perception. It is only when pressed to give an explanation, people might describe the vision system in misleading terms, such as a series of complete "snapshot images" that enter the brain where they are deciphered, with little regard to the active role of the perception and body motion in this process. Yet people do not ordinarily believe vision works as a camera, as this belief is in not evident in their actions. It comes as given that eyes, head and body positions need to be altered to actively probe the environment and to get to more suitable vantage points. (Noë, 2004, 57–58.) In design, the question of how things are perceived might be likewise sidestepped. In the vein of the above example, it might be argued that the working designer, through his or her actions, can't really have a false idea about perception, despite articulating it poorly or in misguided terms. Articulating exactly how visual perception works is vastly difficult, and where such articulation is required, then it becomes possible to make claims that also have consequence to design activity and approaches. Various disciplines, which attempt to define visual perception, have an opportunity to construe models of perception which in turn can guide assumptions in research. As a concrete example, building on a point made by Noë, trying to give computers shape recognition skills via camera images alone may be a limited approach, as animals and people do not actually perceive in such a way (Noë, 2004, 20).

The topics of constructing artificial vision and intuitively useable space are not at stake here. Neither has the point been to discover the most up-to-date perceptual theory and apply it directly into design work. The issue is not so much whether a theory or idea about perception is the most correct or understood correctly, but that it is becomes used for effect at all. Yet to say the excursion to perceptual topics is merely influence or inspiration would be to dismiss the whole issue as trivial, as anything could serve as inspiration. Firstly, even in an open-ended artistic process a certain inner logic would have to be satisfied. Even when inventing a fairy-tale world it would need to follow an internal consistency that satisfies the author's idea of what belongs. It becomes checked against the artist's credo. Here the personal approach is linked to sufficiently certain, credible facts about perception, maintained by the conviction that the original visualization on visibility says something meaningful and that the personal theory is not wholly arbitrary.

Summarizing the literature influences

The content in the artefact suggested readings toward the nature of spatial perception. What is sought after here is a possibility that the design of spaces becomes coloured by ideology that derives from or is grounded to different interpretations of space. The readings on perception became a way to continue the trajectory started by building the computer visualization artefact. In the first artefact case, the finished design was followed by exploring directions in literature. This was initially achieved through seeing the obvious resemblance between the visualization, Benedikt's (1979) work and Gibson's (1986) illustrations. From here on the thematic setting for the thesis work becomes established. Both the designed object and the ensuing interpretation support the building of a spatial conception.

As the artefact initially became seen as an exercise in computational algorithmic generation, the readings were directed towards that topic. This supplied the initial interest toward the topic of generation. Later, generation became to be understood as an organic principle in a design process, initiated and followed through by the designing person. This will be discussed further in the following chapter. The examples in computational literature gave templates to see a computer program as either a generative tool for the designer, or as a picture or a model about what the maker believes about the topic. To a degree, the two threads of computer generation and spatial perception are two parallel topics. The reality of this design case is that these parallel threads were held active. The initial topic of generative algorithms has brought me back to the question of what the spatial conception suggested by the artefact can be used for. This is not just a matter of the artefact suggesting a direction towards theoretical topics. Also the way and the means the visualization was made with suggested a way of working. In the longer process of the doctoral thesis the threads have fed back to each other.

2.4 Looking back

The following gathers together the insights that resulted from building the artefact and reading the literature. This is done to show how the first artefact served as a motive for making the second artefact, discussed in the next chapter. For these purposes it has been possible to examine the software itself, the pictorial material produced with it, diary notes, sketchbooks and the original master thesis. Even though the artefact spurred initial reflection on the done work, only much later did it become possible to examine the motives for engaging into this project, how decisive choices were influenced and what beliefs were at play. I will open the "looking back on the artefact", explaining the first insights emerging from it, its final interpretation within the thesis and the contribution to personal theory and the thesis as a whole, with notes on the origin and the development of the artefact as a design process and the kind of moves that led to the outcome.

What the artefact seeks to illustrate was a conception of space that is in contrast to seeing space as a collection of static objects. The work had its beginnings in an idea about visualizing the cones of vision in a plan. At some point or other, most people have probably thought about what the volumetric shape of view cone is at a given moment. To architects and designers, this may be even more familiar notion, as some perspective methods make the view cone explicitly visible on paper. The fascination on the topic really started with recreating the view shapes into a computer visualisation. The view cone shape alters organically as the point of origin is moved in a plan. Only later it became an issue how this insight could be put to work in designing new things.

The standpoint here is that the artefact building facilitated the exploration of an understanding of motion in space as it might relate to designing spaces. In this way, to have a conception of space, regardless of whether it is correct or not in the light of the perceptual theory, can serve as a basis for

new design ideas and the framing of the design object. The beliefs that are formed this way, although not necessarily true, are consequential to the design processes that ensue. The spatial conception has to have bearing for design outcomes and action. The first artefact alone does not achieve this without further work. To explain the transition from the first artefact to the two following ones, I will explain how the conception came to be.

Different purposes for the view cone shapes

The view cone shapes have potentially many purposes and roles within a design process. I will review few possible interpretations before I explain the role it has been given in the artefact development process. It is clear that the individual view cone shapes on a plan can help explicate matters of visibility when planning spaces. With the computer software, it is possible to explore how visibility plays out in a plan in motion. It can be used to establish the visibility and non-visibility of objects for a chosen path. A few ways present themselves how the artefact might play its role out in concrete terms. Following a pragmatic direction, immediate applications might relate to the positioning of advertisement or information regarding fire exits, first aid kits and so on. Undesirable appearances could be hidden from sight, or the amount of hiding from some main occupied space could be adjusted. Although these are related topics, focusing on these matters might reduce space into dealings with the objects in space rather than the whole layout itself, the latter which I have been most interested in.

Extending from paths to whole environments, entire plans can be subjected to spatial analysis. Apart from the gallery example cited previously in this chapter, there has been some success in correlating crimes such as burglary and theft from cars with urban topology (Van Nes and López, 2010). The individual visibility shapes have offered different modes of analysis for smaller, interior space. Sophie Psarra has worked on architectural spatial narratives, examining Mies van der Rohe's Barcelona pavilion through applying the shapes on the plan (Psarra, 2009, 43–64). In contrast to the previous example, Psarra's analysis is not behaviouristic or quantitative, but helps extend the dialogue to existing views in architectural-theoretical literature. Daniel Koch has argued for the use of visibility cones when examining department store space in his doctoral thesis (Koch, 2007, 78–80). In a shop environment, not just logistics of motion and access but exposure, importance and availability are communicated through visibility. Ignoring the larger themes of Koch's thesis, the view shapes superimposed on the floor plans can help demonstrate how thematic departments or demographically targeted areas become managed through visibility. (Ibid., 212–215.) The spectrum of these examples seems to validate the idea that visibility issues can be worked into spatial discussion at all scales. My approach has not been to discuss the usefulness of the tool in analysis or let it prescribe locations for objects. The way visibility is treated in the examples suggests there is a mode where space becomes understood through its visibility. The visibility issue becomes a frame for understanding space, the overall conception of space.

The artefact as a starting point for the research

The first design tool artefact has been here examined as a kick start to the entire project, setting up the theme for the later tools. In this chapter, the process of coming up with the artefact has been examined in some detail. Here, the overall journey will be examined in terms of design moves within the design and research process. The overall progression is shown in Figure 18. Looking back, I am now more conscious of the bag of tricks and techniques that were at that time in my possession. I want to emphasize that the artefact resulted from work and actions that were not immediately related to the questions of visibility it helped to clarify. The interpretation of design moves as generative is based on the work on the second artefact, and this discussion will be opened up further in the next chapter.

All in all, the work on the visualisation emerged from my dissatisfaction with the conventional ways of representing space, such as plan drawings and sections. This intention was by no means clear, shown in the way I had to rely on a plan drawing convention after all. The possibility for this visualisation is based on the properties of plan drawings and this was to some degree an unavoidable consequence. Plan drawings can depict geometrically simple, conventional urban space or ordinary apartment layouts. For example, forest and natural environments are more readily depicted by a topographic map, and even then it is clear the geometrical abstraction is stronger than in floor plan drawings. It is less easy to produce view cone shapes out of a thick forest space, so there is an affinity between the view cone shapes and the way built environment is laid out. Therefore it can be said the view cone shape and the ensuing space-time form is really produced from the geometry of the plan, which in turn is derived from the artificial environment layout. The artefact concretizes an idea of space as generated by movement through form. It enforces concentration on one

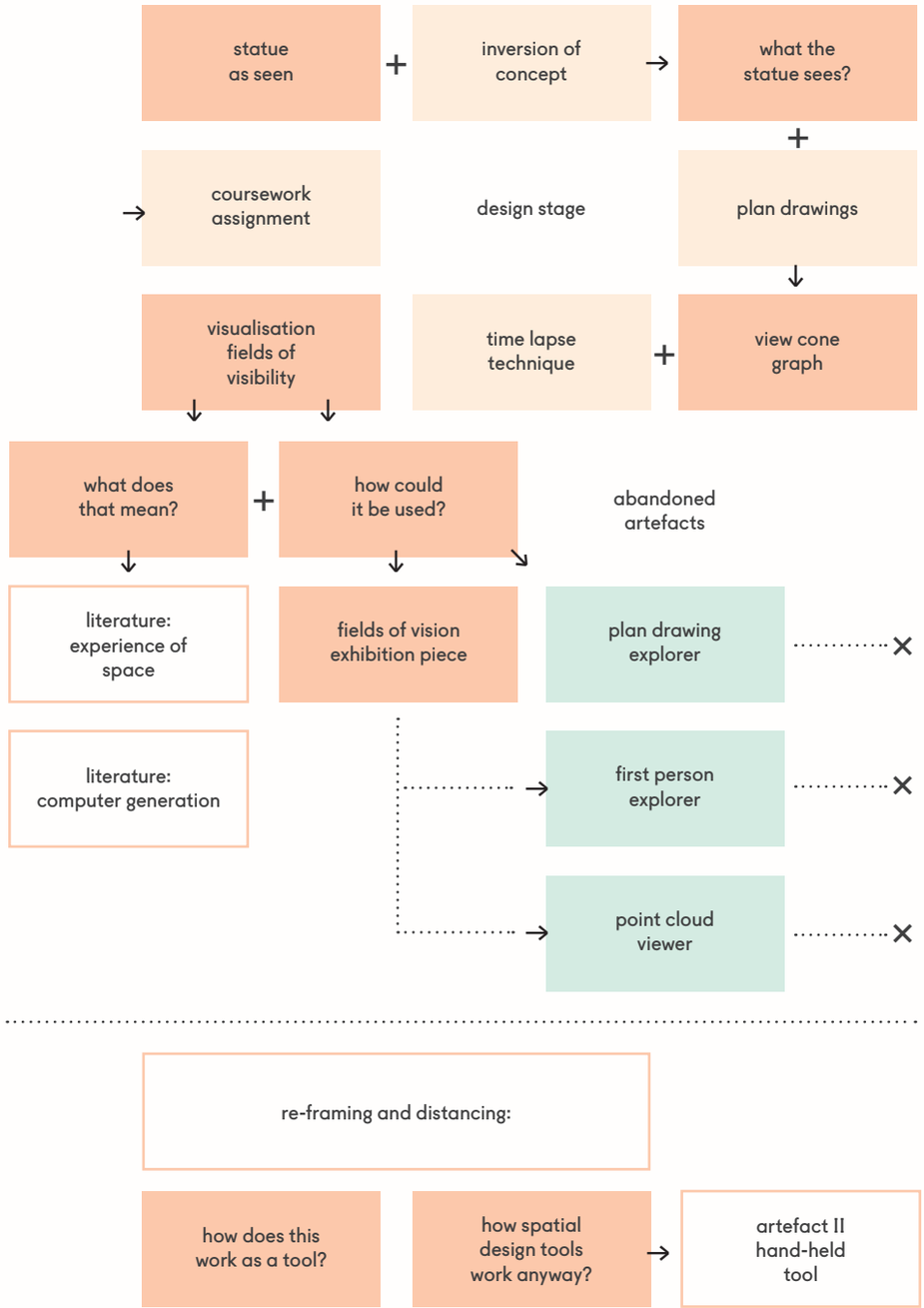


Figure 18 (p. 89)

The progression of the first artefact and subsequent stages of readings, questions and exploration. Notable abandoned spin-offs are depicted as gray boxes. The progression ought to be considered overall when identifying the motives for making the next artefact.

aspect of space, the relatively geometric environment in cities and buildings.

The visualization is a result of combining known simpler techniques and mediums, producing an outcome that was not simple to interpret. If thinking on visibility did not produce the artefact in the first place, then it has to be asked what is it an outcome of? It is possible to trace this to a design technique which could be called an inversion of a concept. When an idea or definition arises, it can be reversed, either simply by reversing words or attempting to invert the actual concept. A simple example would be to exchange the geometry in a chair seat and legs, something that can quickly be explored through a sketch. Research into creativity in design terms this kind of move or procedure as combination, mutation or analogy, when previously existing components are tried out in new roles (Rosenman and Gero, 1993). Such inversions and reversals are stock and staple in a design process, and a creative leap can be characterised as the one fruitful viewpoint that emerges from making these moves, helping bring the design process towards closure (Cross, 1997). The viewing of the statue became the origin point for the artefact work. The moment the statue was understood as something seen, applying the inversion technique led to think of what the statue "sees". Putting multiple shapes together to form the overall three-dimensional shape was done in a vague expectation of an interesting result, not an expectation it would illustrate a conceptual notion of space. Significantly, the artefact did not result from a prolonged consideration of space, but on the other way round, the visualization started to provoke thinking on space.

In this case, the initial idea about view shapes was quickly joined by assumptions about using a specific representation (the plan drawing) and a computer program as a device to produce the motion shapes. In hindsight, these moves may

be considered premature, as these choices strike as obvious ones. But these choices also show how a generative move works within the design project, and also, that the repertoire of favoured moves was used to come up with the artefact visualisation in the first place. Different, already known concepts are connected together in an attempt to produce something unprecedented, either a novelty or a way of seeing the task at hand differently. Although this quest for something interesting and novel differs somewhat from a situation where a mechanical problem presents itself, the process for producing tentative material is the same. The technique relates to Schön's concepts of seeing-as and the generative metaphor (Schön, 1991, 182–184). In seeing-as, the situation becomes understood in terms of something else, without necessarily understanding what the similarity is. The generative metaphor is a definition of a thing or situation in a way that both permits and suggests new ideas arising from it. What happened here is simpler, as the inversion did not rely on an analogy but on a simple interpretation of a situation. Before a concept can be inverted, it first needs to be defined in a way that permits the inversion. This is where the resemblance with seeing-as is apparent.

Building a personal theory of space

Figure 19
Figure 20

Seeing-as and framing as described by Schön are specific instances within some task or project. But it can also extend to how the designer frames his task or role, where it ceases to be just a one-off trick utilized in one project. To have an overarching belief about a way to approach a thing, one may start to talk of a personal theory. Schön suggested

frame analysis as a way for professional practitioners to become aware and critical of how roles and problems become framed in their practice. (Schön, 1991, 309–311.) The building of the visualization can be seen as an act to initiate one such analysis, of how the object of spatial design becomes set. The personal theory of space is a long-term device, and not a one-off way to frame a single situation. My first ideas about spatial design, as much as I can recall it, was that it is like design of big furniture, with built frames holding together the container for people's activities (Figure 19). This was made manifest in the way I drew spaces as interiors as boxes with items inside. This way I had fixated on a way of working that had emerged from building furniture.

This is not an essentially wrong view, and I have probably never abandoned it fully. Nor does it need to be, as the repertoire of spatial conceptions can be expanded and not merely replaced. The idea can very well form a basis for a practical approach to tasks in spatial design. In the generative interpretation, the conception is neither a wrong or right one, but something that permits the conjecturing of outcomes in the first place. What can be criticised is the overt reliance on any one idea about space. I had felt that the box-angle alone was insufficient to me and I wanted to widen my perspective. How the dissatisfaction manifested itself materially was the feeling of inability when drawing spaces. This is a theme that will be opened up more in the third artefact case, described in the fourth chapter. Understanding space as "big furniture" was a personal obstacle, not necessarily a general problem within the field of design.

For examining the frame further, I have borrowed the term "spatial conception" from art historian and theorist Sigfried Giedion (1982). He used it to denote the large scale differences in understanding of spaces in various historical eras, reflected in major approaches to building architecture.

In an introduction to the 1960s edition of *Space, time and architecture*, Giedion gives a summary on the idea. The Egyptian, Sumerian and Greek spatial conception resulted from an interplay of volumes that "emanate space", with disregard to interior space. The Roman period would have, with its advances in vaulting technology, brought forward a second conception where space was equated with hollowed out interior space. The third space conception associates with modernism and is about the abolishment of the perspective viewpoint. Although the box-conception prevails, the modernists also questioned it by presenting interpenetrations of the inner and the outer space. (Giedion, 1982.) As historical research, Giedion's formulation does not probably bear scrutiny, and he appears to have been more of a theorist with a view towards effecting change and influence. As such the theory can provide background for various design approaches, which is more relevant here. I also find the idea of spatial conceptions in this sense more valuable on a personal or local level, as a belief base for how a spatial design task becomes framed and approached. The spatial conception is something distinct from a concept of space, as the term conception draws attention to the way space is conceived, or borne out. Giedion acknowledged that the different conceptions owe to construction technology, specifically the vaulting problem and the space solutions that emerge from it. This I interpret to mean that the conception also involves material making and building.

The first artefact's role in the thesis project

It is now possible to summarise how the beliefs about space emerged during this process, related to the central concepts in the dissertation. Algorithmic generation of form gave rise to thinking about the role of computers in design. I applied many conventions and techniques, such as plan drawing and time lapse to make the idea work. In hindsight, a set of generative design moves were instrumental in devising the artefact. The case on the whole turned my eye toward generative concepts. I have interpreted the process as a way of developing and accumulating a way of picturing space. Together with the literature, the first artefact established groundwork for thinking about space and set the tone for research. This conception became the basis for further design activity, where the making aspect became more central. As the next focus was to be on tools, it was practical to keep the most generic understanding about space as straightforward as possible. Gibson's way of grounding meaning of space into a basic perceptual structure provided a sober backdrop for this. To me, it meant leaving out social interpretations or spaces as sign systems. The experiences with the first artefact helped build confidence in the mode of exploration, where questions would arise during and after the design experimentation. The experimentation and exploration presses the research-oriented designer towards further directions. This process came to be more focused and deliberate in the second artefact case.

The final interpretation of the artefact within this thesis is found in just how it sets up seeing and visibility as a conception of how space is experienced in motion. Besides the pragmatic applications, it is more significant that matters of visibility in space came to attention at all, as a result of building and trying out the computer visualization. The visualization and its interpretation becomes a focal object, rather than the things it might be directly used for.

Playing with the tools has brought visibility and spatial perception issues into the foreground. This conception of space is built out of visibility, and not for example building components. The artefact visualization together with its interpretation is accepted as a starting point for a designer's personal theory of space. In one sense the visualization as a design tool can also be interpreted as a diagram. The visualization becomes an in-between design, ambiguously suggestive graphic summation arising from an analysis of phenomena, not necessarily traceable in any works that might emerge out from its use. Characteristic to diagrams, real-life phenomena are translated into another form. More broadly, the question is about the way design outcomes stem from perceptual beliefs or a spatial conception. For example, Norman's interpretation of affordances (Norman, 1988) may be seen as one adaptation of perceptual questions, translated to a condensed format that generates design outlooks.

It has now been described how the view cone shapes directed the literature review and an attempt to build an interpretation of the shapes. Here, the visualization establishes visibility as basis for addressing the spatial design angle through further design tool building. The perceptual literature supports an idea that visibility is never purely visual, but one modality through which the environment becomes perceived. I have attempted to follow this route further in later artefacts. As such the creation of this artefact and the ensuing work has been a move that sets the stage for the later design work. First, the visualisation was built without clear articulation of its meaning. When working with the interpretation, the visualisation showed ideas that were ahead of what I could grasp in the way of making. I had set myself an elusive, distant goal. The question was how to make this perceptual understanding of space felt when

creating actual design proposals. In short, what procedures and tools could actually bring me closer to knowing how, rather than knowing that?

Building a hand-held tool for reflecting on design

Figures 21–35

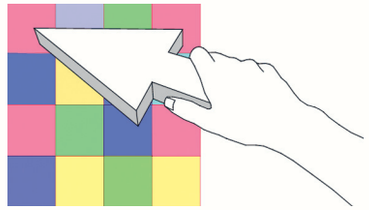


Figure 21

The hand held device concept. Colour values are scanned from the environment and transmitted directly to a computer or stored in the device.

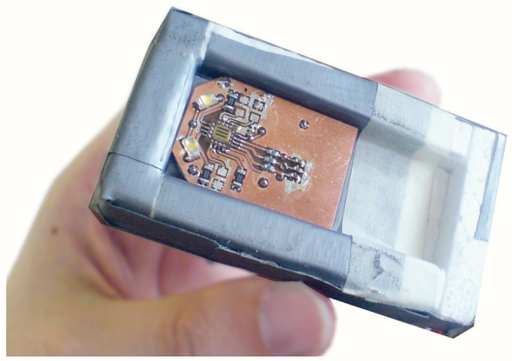


Figure 22

A colour sensor module in a prototype casing. Connected to a microcontroller, this setup was sufficient for exploring the possibilities of the sensor. The 5 mm x 5 mm sensor unit is at the tip of the module, between two LED lights. The module was designed by Jussi Mikkonen, MSc.

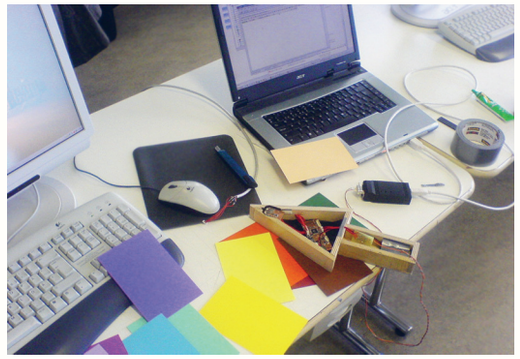


Figure 23

Early design experimentation was firmly tied to the desk. The programming environment, paper knives, duct tape and glue were all kept handy.

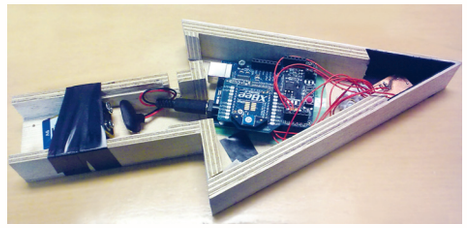


Figure 24

The first working prototype with a wireless interface. This figure shows the device upside down to the position in use.

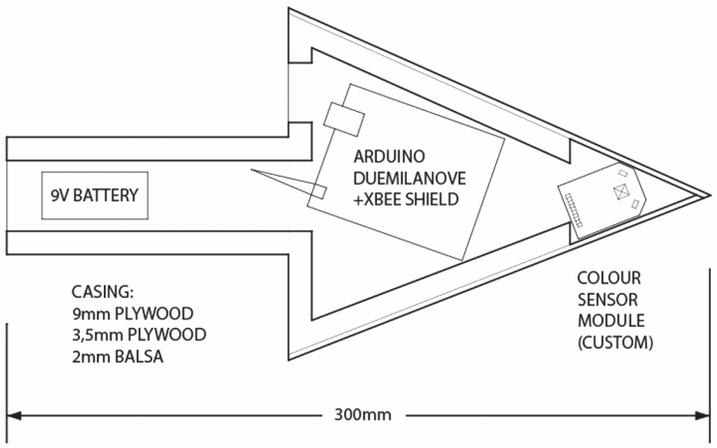


Figure 25

The schematic for the first definite working version.

Figure 26

A digital painting made with the sketching software, using the device for feeding colours. Here the colours are not from the environment itself but from paper pieces.

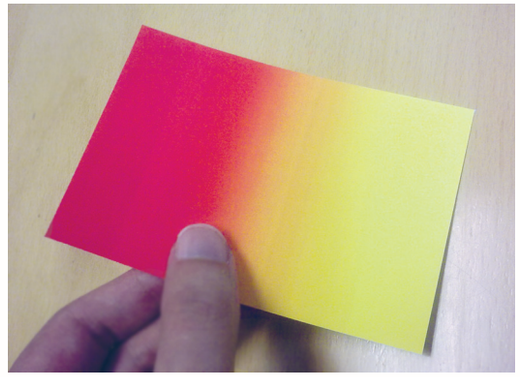


Figure 27

Colour could be adjusted multi-dimensionally with bending and adjusting a colour-gradient card in relation to the sensor angle.

Figure 28

Doodles created by other designers with the sketching software. In the left- and rightmost pictures the outcome is an over-drawing of multiple tryouts or sketches.

Figure 29

The setup at Suomenlinna. The surroundings provided rich colour variety and different surfaces and environments for trying out the device. At this point, it was still necessary to carry the laptop around. The setup did not work well outdoors, and the intended task was completed with watercolours.

Figure 30

The setup for replicating colours with watercolour brushes.

Figure 31

Seeking to match the waer colour tone with the chosen target.

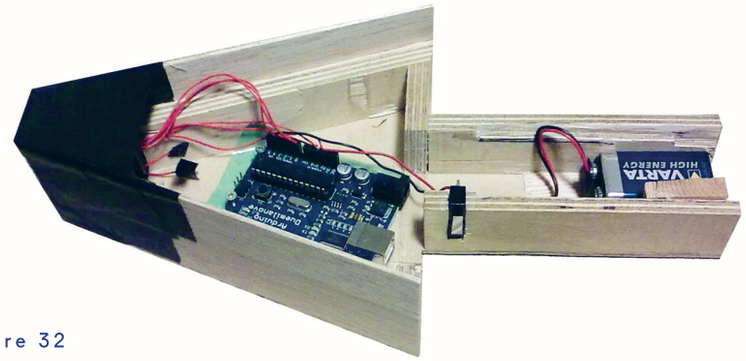


Figure 32

The revised version. The colour sensor module is housed vertically at the end of the box, now shielded better from outside light. In this variant, the wireless transmitter has been removed. A button has been added for storing the current colour.

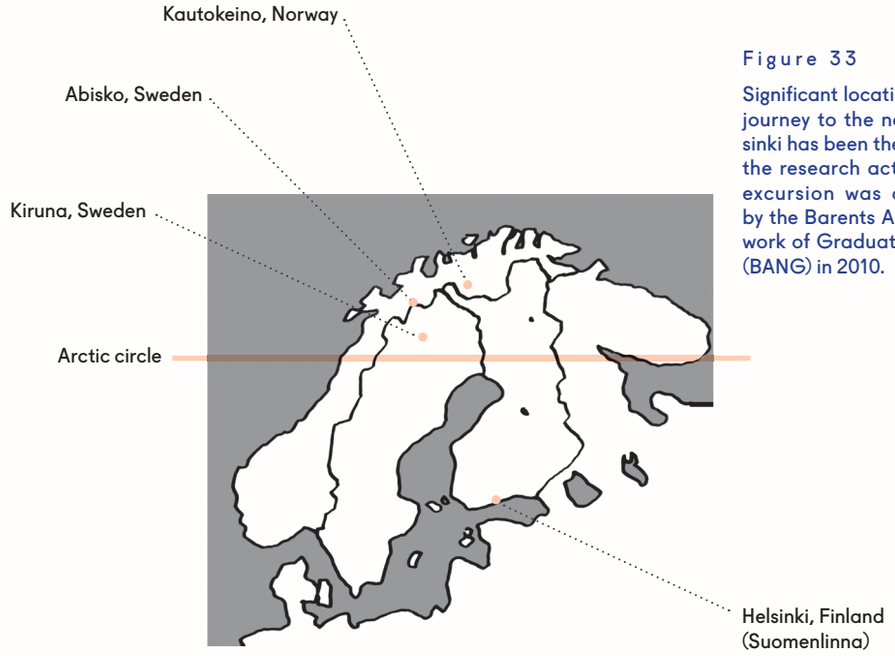


Figure 33

Significant locations in the journey to the north. Helsinki has been the base for the research activity. The excursion was arranged by the Barents Arctic Network of Graduate schools (BANG) in 2010.

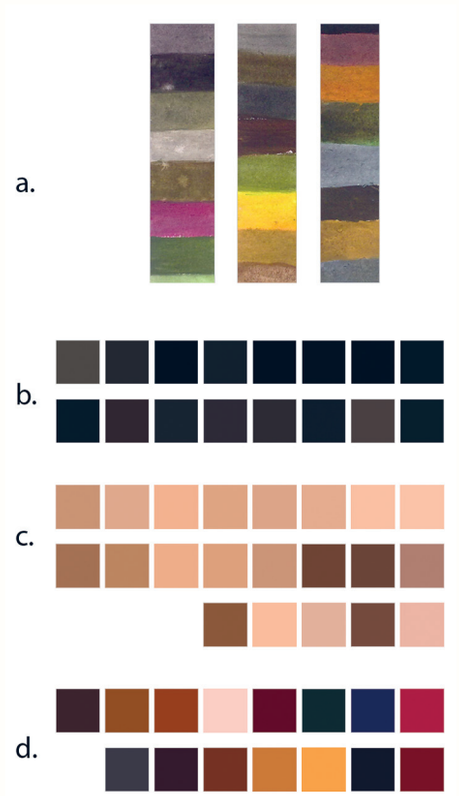


Figure 34

Colour collections. From top to bottom: Three collections from Suomenlinna, made with watercolour after the device broke down. (Collection a.) Below, collections from Kiruna mine, Abisko research station and a motel cottage at Kautokeino. (Collections b, c and d.)

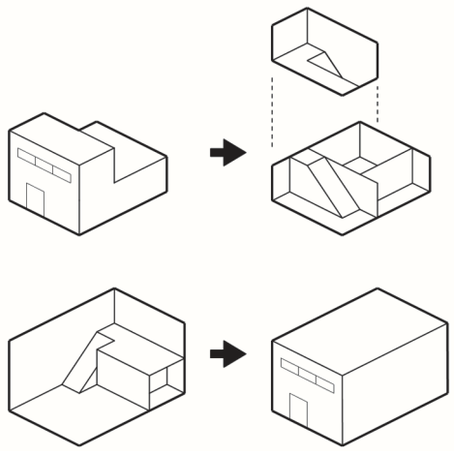


Figure 35

Illustrating Herbert Simon's "outside in" and "inside out" generative approaches to designing a building. Above: The articulation of the interior is allowed to result from the definition of the outer shell. Below: The outer shell follows from the interior solutions.

3. Building a hand-held tool for reflecting on design

The second artefact is a physical pointing device with an electronic colour sensor. The tool is used for collecting colours from a site, which are then made into palettes. The artefact becomes a focal point for discussing the act of narrowing down or directing the initial ideas in design, seen in terms of generative moves. The making and the testing with the tool are examined, and through interpretation help articulate an understanding of design.

"[...] the world really detests ideas, it loves tricks. Sometimes, under the guise of trickery, ideas have been put over."

– Man Ray (1988, 296)

From vision to touch

Figure 21

After the previously described visualisation and the resulting exploratory angles were exhausted, I decided that a second artefact project should be initiated. This time it would be a hand held device. This new direction becomes explained from the aftermath of the first artefact case. Even if the spatial visualisation helped frame aspects of spatiality, this did not in itself open up a view into design activity. The question remained how does one design with the conception of space that resulted from the work? These considerations provoked me to build a more physically oriented artefact, one that would be used in direct contact with the surroundings. This new device would distinctly achieve some outcome in action. The making aspect in design could be highlighted through looking at the tool, and the tool building itself is examined, an opportunity which did not present itself easily in the first case.

The second artefact is a hand held object, which transmits colour values from surfaces it touches (Figure 21). With this tool, I wanted to pursue the idea of building the tool as a way

to begin discussion on design moves as arising from tools. I hasten to note that even if the artefact is based on a colour sensor, the artefact and this chapter is not about colour design, colour theory or the role of colours in the environment. In its role as a colour collector, the tool is meant to underline the situation where the designer has to relate to a specific site or location. The artefact case was initiated for exploring the role of building such a device, using the case to open up design literature and reflect on the things done. Thus the second artefact opens up a different avenue for reflection than the first one. Whereas the first artefact brought to light topics about space and experience, this second one is used to address the activity of designing. This way, the building and using of this artefact is also an act of defining and isolating a topic within the research project.

The tool is viewed from the angle of generative design moves. The more theoretical discussion, arising from literature, relates to the significance of decisions and moves within design activity. The notion of conceptual moves within design, as reversals, combinations and mutations (Rosenman and Gero, 1993) and creative leaps (Cross, 1997) were mentioned in the previous chapter, as the visualisation was seen in part to emerge from such activity. As I explored the idea of design tool through building the second artefact, the work came to point towards the topics of self-imposed constraints (Lawson, 2006), and the establishment of a primary generator for the design process (Darke, 1984). These will be discussed after describing the making of the device.

Constraints might seem essential to design generation as a constraint often implies a reductionist strategy, an important element in designing. Bryan Lawson's overall model of design problems suggests a variety of constraints, with designers, clients, users and legislators as "generators" of constraints. The value of designer-set constraints is in setting up the design task or the problem in a beneficial way. (Lawson, 2006, 90–111.) Norman Potter went as far as to define designer as one who "transforms constraints into opportunities" (Potter, 2002, 60). To use Lawson's terminology, it is the designer-generated constraints that are of interest here. Here I am not so concerned with physical constraints, but the ones that are set by the designer or rise from the personal design credo. Thus I do not consider the qualities of physical world as design constraints in this sense, but as a backdrop within which all activity must take place. This constraint and direction can become set through the choice of a tool or a medium. Here the tool-building is seen as a promising activity for examining one's own understanding of this aspect in the design process. Design moves are seen as arising from tools and from working with tools and materials, namely the physical artefact presented here. Having said this, I disagree with the word constraint especially when it comes to design-originated moves and thus I do not follow its use rigorously in my analysis. To me the term seems to set up design activity in negative terms, both in tone and as a matter of viewpoint. One may just as well put focus on what design moves and decisions achieve rather than how they "constrain". Thus the word would be better reserved for the non-negotiable elements in the brief given to the designer.

For the practice-led researcher, it is also important that the tool making and its use supports dialogue with literature that heightens the sought new understanding. The motive for making the artefact primarily arises from a need to understand the tool-building angle in design for the purposes of the thesis. Picturing certain aspects of design through the tool and its making lays the basis for interpreting the artefact through the literature. I will briefly bridge the perceptual discussion in the previous artefact chapter to show how the artefact is a continuation to that thematic.

As Noë (2004) puts it, visual perception and tactile exploration have a shared root, an undergirding principle. Thus vision and touch are but modalities of the same principle, and not essentially different channels of sensations. This is clarified through the example of an innately blind person. Instead of vision, Noë offers that the probing "tap-tapping" of the blind with a stick should be the paradigm for all perception. How the blind perceive is not drastically diminished as a seeing person might imagine. (Noë, 2004, 1–3.) The properties of environment are out there, and the person has access to it through the means provided by the body. The understanding about the layout of the environment is not inferior for the touch, as the grasped layout itself is not about touching or seeing. For example, roundness is not a "visual" property. (Noë, 2004, 98–99.) With smaller objects this becomes most apparent. With closed eyes, feeling the object in hand, its shape becomes appropriated even in detail. A seeing person might be tempted to assume that when a visual appearance of the object becomes imagined, it has become appropriated. In the case of the innately blind, despite that the seeing-modality is not present it is still clear the object layout must have been appropriated.

The first artefact seeded considerations on visual perception, whereas the hand held artefact case was initiated to build distance from that visual modality. Yet the action is still collected to a single, central point, the position from which the device is used. Previously this point was equated with the emanation point in the geometries of vision, but here the locality of touch becomes the origin for design work. After explaining these beginnings as the initial motive for the second artefact, the touch modality will not be further discussed as it is not intended as the focal point for discussion in this chapter. Instead, the discussion opens up design theory that relates to the design-conceptual moves that the

making and using such a tool entails. When collecting materials from a site, some designers might conventionally rely on photographs and dimensions, whereas others might want to build site understanding culturally or historically, or through some connection to the people living at the site. The artefact puts these diverse approaches aside and reduces the site data to a single pixel that needs to be physically collected via touch. This act of simplification helps conceptualize the designer's relation to the site for the purposes of this research project.

Looking back at this activity, the artefact stands as the second object for reflection, something again to be deciphered and interpreted. This chapter is a recollection of how the object came into being and how it started to point toward further development and interpreting the artefact. During the course of this process the artefact is tried out in different roles. Initially the device is tried out as a component in a computer sketching program, and later as a means for building colour collections from sites, as described above. The device was tested at various outdoor and indoor sites, where it was used for collecting colour palettes. The collecting activity became a key for reflecting on the role of a tool in design generation, whereas as a sketching augment the device prompted to direction where skills are seen as important components of personal theory.

3.1 Building the hand held device

The building stages are described here more closely than in the previous case. This is to emphasise the constructing as significant in arriving at the concepts that emerged later. The hand held tool device was realised in two major versions. The first version worked as desktop device, and it could not be really separated from a laptop computer. Additionally, the way it was shaped meant that the colours could only be effectively picked from a flat surface. This version was used in conjunction with sketching. The later version addressed the needs for a device that could be carried around to various locations. At this point, my deliberate research brief required me to remain within the boundaries of digital tools and possibilities of mixed digital and physical material objects. A somewhat similar device has been built in the Massachusetts Institute of Technology Media lab. With the tangible I/O brush the research focus appears to have been on enabling a variety of novel uses that a camera-based brush allows, such as capturing textures and painting them directly on the screen with the same device. The group used the tool to study children's creativity. (Ryokai, Marti and Ishii, 2004.) In contrast, the device presented here is able only to record colours from the environment, and not images or other measures of space. It is also not possible to draw with the same device. Although this artefact has been tried out as drawing assistance, eventually the main thrust is towards building colour collections from sites. The overall intent has been to examine a self-building process for the purposes of a practice-led research into design tools. From this overall viewpoint, it becomes meaningful to discuss the ways the same tool becomes tried out in several roles and is modified during the progress. This is another reason for examining the building process in more detail.

Making the first prototype

[8] The colour sensor is ADJD-E622-QR999 from Avago technologies.

A university course in interactive prototyping provided an opportunity to build a device based on a colour sensor. At this stage, the purpose was to make something I could realistically expect to work, and continue building on it later if possible. The colour sensor was discovered from a catalogue of electronic equipment, supplied during the course[8].

Figure 22

These first identifications were important, as the sensor became a major seed for the entire artefact and what followed from it. It was not chosen randomly, as the colour sensor was recognized to allow a wide range of uses, compared to, say, a microphone or a distance sensor. It began to suggest different applications almost immediately, just as long as the part would be housed in appropriate casing. Not all uses would even need to be colour-oriented. One driving motive was to avoid a computer screen centred approach and instead explore combinations of physical and digital matter. I felt I had already worked too much with on-screen objects altogether, culminating in the first artefact and its offshoots. Even so, this was not entirely avoided during the process. The safe haven of the screen software held a strong attraction to me.

The device was created in collaboration with an engineer, who built the circuit board for containing the sensor, and also supplied a microcontroller board of his own design. The engineer's presence heightens the significance of collaborations and available competences in a generative design mode. The electronic parts and equipment came to be chosen through his expertise. The necessary software framework for accessing the parts was also his working, and this enabled me to experiment freely with different ideas, toying with the custom built microcontroller board connected to a colour sensor module. The possibilities were explored by trying out different enclosures for the colour sensor module. A liquid crystal display (LCD) connected to the

microcontroller was helpful in initial stages for reading out the sensor values directly (Figure 23). This helped build a practical understanding and a feel of the dynamic range and the responsiveness of the colours sensor when in actual use, giving a clearer idea of the tool possibilities.

The hand held device was then built as a casing around hardware parts that were realistically available at that point. The sensor capabilities were explored by moving the sensor around by hand (Figure 22 and Figure 23). The tool came to grow around the sensor from these early experiences. The challenge was to make the device functional in the first place, as working with electronic parts was not familiar to me. The challenges related to the properties of the sensor, which can not really identify colours in any absolute way. Lighting and other conditions drastically affect the readings, and this put clear constraints on the device shape. The casing had to cover the device effectively so as to make different colour readings comparable to each other. All this brought down the amount of potential uses for the device.

The first concept that was brewing was to use the device as a physical counterpart to a computer desktop pointer on screen. Different colour surfaces in the physical environment could be used for activating different functions inside the computer. The colour surfaces could be located anywhere in the immediate environment. For example, pointing a red card could run a command on the computer desktop, and a yellow card would run another. The overall arrow pointer shape for the device arose from this concept. The form was mostly intended as a humorous reference to the pointer in a graphical desktop environment. The envisioned outcome from this in my mind was more of a parody or a commentary than a serious competitor for a computer desktop. But the arrow was found to be an adequate shape for containing all the minimum electronics: the power source, microcontroller and the sensor module (Figure 25). This choice also established the device as a definite hand-held tool. Other concepts would have placed the colour sensor in some fixed place in the environment. This choice could have limited the uses whereas the hand held device could still be fixed into a location if desired. I wanted to perpetuate the flexibility of potential uses for a while longer, as it was still unclear in what direction it would be ultimately taken to.

Figure 22
Figure 23
Figure 24
Figure 25

In the beginning, the device was wholly built out of parts supplied or designed by the engineer. Minor but persisting inconveniences prompted a later move to off-the-self parts. The device was rebuilt with a ready-made Arduino Duemilanove board, which has a programmable microcontroller, electrical inputs and outputs for connecting sensor devices. The colour sensor module (Figure 23), containing the lights, was retained from the earlier configuration. The Arduino building blocks also simplified the transition to wireless. Only after these changes were made did the device become reliable enough for a variety of situations.

The colour sensor module is placed near the tip of the device, close to the surface that is to be read. For use situations, the casing top was covered with a cardboard lid, taped over the device. The casing prevents outside light sources affecting the sensor reading. Two light emitting diodes (LED) are located near the colour sensor element, for lighting a surface for illumination. The battery is placed within the handle, and the board was made to fit inside the arrow bulge. The clear separation of parts helped the exploration as the parts could be removed easily for maintenance. Designing the casing ceased to be of central interest, and the first wooden casing, made from plywood, was retained throughout the work. The practical reason is that work on a more articulated casing would have prevented modifications, but this decision also helped save time.

The device as a sketching augment

The beginning work with this artefact was marked by exploring various directions. Much of the initial design choices were driven by preparation for contingencies, as the artefact was not created with only one definite purpose in mind. The basic setup began to suggest different ideas, such as a way for using the device as a physical pointer for computer. Just as during the first artefact case, some directions were pursued only to be abandoned, and these will be briefly examined below. As mentioned previously, the pointer shape related to ideas about physical-digital connections in the environment. As soon as the device was built, it seemed inappropriate to use it as a physical pointer for launching commands within the computer. Most crucially, this direction seemed to lead outside the pre-determined brief of building design tools. Using the colour readings as such seemed a more attractive direction, as it showed more potential for skilled use. Two directions came to have consequence for the project. In the first, the device was employed in computer sketching program (Figure 26). The second application relates to collecting colours from different sites and locations. These two roles come to have a bearing for interpreting the artefact within the confines of this thesis.

Figure 26

Experimenting with the colour sensor showed that it could read and transmit colour values to a computer rapidly enough for smooth, linear colour changes. When drawing a line on screen, whilst adjusting the device position, the colour of the line could change smoothly. Generally, given that drawing software does not allow flexible real time changes in the chosen colour, this was an opportunity to experience something unconventional.

The tool as sketching aid was further explored through trials with four fellow design researchers. Some of the results are shown collected in Figure 28. The setup included various coloured cards and the sketchers could comment on how this setup appeared to them and what might be done with it. The experience and the comments harvested suggested that the device was not immediately intuitive, although some could see the attraction in replacing conventional colour selection with physical cards. Two-handed drawing and having to draw with a graphic tablet, and not directly on screen, provided additional difficulties. Personally, over time I have learned to use the colour input simultaneously with drawing, acquiring a certain rhythm to do so, but such learning takes time. One comment regarding the situation as "like playing a piano" seemed very appropriate, as handling the setup would require a skill somewhat comparable to playing chords and melody with separate hands, with the added trial of having to keep an eye on the screen. The most positive experience for me was to discover that a single card could be used in conjunction with the colour sensor, modulating the colour tone and saturation by subtly altering the card angle and position to vary the amount of reflected light in a very tactile manner (Figure 27). In traditional mediums like oil painting, it is possible to invoke subtle colour variations at the same time as the brush moves along the surface, and the setup allowed something similar to happen on the display.

Figure 27
Figure 28

Importantly for the next artefact case, where drawing will be addressed, I felt an increasingly pressing need to examine sketching and drawing itself, a topic that was avoided during making the first artefact visualisation. The artefact in this role provided a way in to the topic of skilled use of tools as seen in the contrasting experience of my own and others reactions to the tool. My previous reluctance to go in this direction arose from the fact that sketching is a very common entry point in studying design and design creativity. The choice to concentrate on individual artefacts and design tools was in fact meant to disrupt the equation of

design with sketching. The new need became decisive both through my own experimentation and the examples that arose from the tests with others. I saw that my experience in the topics of both traditional and digital mediums, coupled with my new found conceptual understanding, would allow me to dissect and discuss sketching experiences. This is done in conjunction with the third artefact case, described in the next chapter of the thesis.

3.2 Experimenting with colour collections

The other major direction for exploring the device concerns creating colour collections from different sites. The device was taken to outdoor sites, with the purpose of collecting colour sets from different locations. This idea was derived from a common practice of interior designers and architects who collect colour maps as part of data gathering. The colours, collected using the device, would stand as the definite material gathered from the site. In the first experimentation, the setups were documented by camera for the purposes of illustrating the settings, but in the later situations even this was avoided. This was because I was worried that my subsequent reflection might be based on the secondary materials such as photographs on the tool use and not the tool use itself.

The tool has been used for collecting colour palettes from different sites. The first tryout was executed at the island of Suomenlinna, located off coast of Helsinki, in the summer of 2009. (Figure 29) At this time, the tool was still connected to a laptop by an "umbilical" cable, which transmitted the colour values instantly to the software.

Figure 29

Figure 30
Figure 31

This first tryout did not work as intended because of a device failure, which turned out to be very stimulating for reflecting on the device and its interpretation. For some reason or another, the colour sensor refused to transmit the required information. Also, working outdoors with the laptop together with the device proved to be cumbersome. Besides other problems, the casing leaked in light, which meant that the tool could not be used, even if it had transferred data accurately. This utter breakdown of the setup prompted me to execute the same task with water colours, without using the digital tool. This unexpected situation made me reflect on the underlying concept I was seeking to do. The goal of the collection was not dependent on any specific tool, but I also found that I'd still prefer some tools over others. It is important to note that tool building still preceded any such insight, which is to say it would not have occurred to me in the first place to do such a colour collection with water colours. The incident of the tool breaking up and rescuing the task with the water colours was pivotal to seeing the position of a design process within the frame of a "personal theory", both in this one tool development case and the whole research, although the understanding for why it was so only followed later. Crucially, the issue comes down to the question why a certain approach seemed acceptable for fulfilling the task. As an example, I would not have accepted a camera, but used water colours for replicating the colours (Figure 30 and Figure 31). I have no great interest in using photographs or video as means to forward design, and to a degree, all the three artefacts partly result from this disinterest. I cannot reflect effectively on a direction not taken, but I can note that the choice is indicative of

my personal approach.

The construction of the tool, as described above, was much driven by the possibilities of getting the device to work in the first place. Yet the larger process of directing the project towards the colour collection goals is not so easy to define in material terms. Here the motives for doing the work are instead underlined, as there are multitudes of occasions where the tool development could be turned to one direction or another. These choices were directed towards what seemed more interesting and promising, yet negotiating the available possibilities that the device and equipment afforded.

The revised prototype

Notwithstanding the potential provided by the water colours, there was nevertheless a will to make the device function as it was intended. The experiences in Suomenlinna prompted adjustments to the shape and functions in the device and concept became more decisively about building the colour collections. Other directions were abandoned, so the device parts were rebuilt to better serve this idea. The early version was physically problematic in the outdoor task, as the device had been built upside down in respect to how it would work best there. Previously the sensor opening was on the underside of the device, as it had been intended for table surfaces. The device could not simply be turned upside down. In the new version the colours would enter from an aperture in the device nose, which would both make the colour collection simpler and also prevent the light leakage. Also, the laptop was removed from the setup, as there was no real need to see the colours immediately on screen during collection. The computer was initially needed for storing the values permanently, as all colour values stored within the device only as long as it was switched on. Some options were considered, such as communicating the output values by some means and writing the output down on paper. However, I soon found out that the Arduino board has its own minuscule memory for more permanent storage, which could be used for storing a small number of colour values.

Figure 32

The colour sensor module design and the wooden casing remained from the original prototype. Now the device could be carried to an outdoor environment without having to carry a laptop alongside. These adjustments compromised the original arrow shape (Figure 32). Even though this seemed an aesthetic loss, the arrow shape was no longer really part of the concept, belonging to the earlier computer desktop parody phase. The new tool is a portable unit that can be used for adding colours into a collection by simply pressing the aperture against a surface and clicking the switch. The casing holds the programmable microcontroller board, the colour sensor and a battery for powering the device. Just as previously, the LED lights inside the colour sensor box control the lighting conditions to ensure that the colour scans are comparable with each other. The colour values were stored into the internal permanent memory, and could be downloaded into a computer at a later stage. The single button on the device is programmed to perform different actions depending on how many button presses were used. A single click records a colour, two clicks sends the recording via cable, and pressing the button for an extended time erases the current memory. The tiny programmable lights in the Arduino board were used to communicate the action taken.

Making the colour collections

The making of the tool was guided by expectations and anticipation of its use, leading to create an object that was based on my beliefs of what a design tool could be and what it does. Then, the tool together with experiences about its use became means to examine design moves as they are suggested by the built tool. Both the building and tryout activities become examined as a chain of exploration. The device is a concrete object, the use of which can be reflected on in order to outline and make the actions more explicit for interpretation. Eventually the work would bring out the personal theory element at play. The failure of the device in Suomenlinna provoked substantial thinking on why the tool was being used in the chosen manner in the first place, and why it was still desirable to build a working version of the digital tool. The tool was not merely a means to an end, but also had become an end in itself. The failure of the tool made me to fall back on using brushes, which was not a random choice: brushes and paints were already, for me, an established way of doing things. This moment was when a conscious image of an artistic credo began to emerge, and also the question of a personal belief as a source or filter of design ideas. From this point on, the design work started to have qualities of an artistic process.

One year after the Suomenlinna situation, the device was next put to deliberate use in a trip to the northern Lapland[9]. Taken together with the Suomenlinna experience, there is an aspect of travelling present with this artefact case, although its significance should not be overstated. Journeys and travels may be another spatial aspect that could be reflected on, but this topic is not pursued here and I do not feel that this tool really allows a handle into it. I also see the discussion built in this thesis does not hinge on these travel experiences, so I will only briefly summarize the taken activities. Apart from being inspirational, the journey affected the device use in practical terms. As the travelling between different sites in Lapland had been pre-arranged, I could mostly concentrate on identifying the various opportunities the sites presented for trying out the device. The trip set a timeframe and also certain conditions for doing the experimentation.

Figure 33
Figure 34

In contrast to building the tool and experiencing its breakdown, there is very little to say about actually collecting the colours. The device was put into use when something in the environment provoked curiosity. This was always a setting which appeared to provide either a rich, promising environment for the device, or a challenging situation. I only took the opportunities when the device could be used discreetly, as I did not want to disturb anybody with my work. At this point I had come to consider the tool as private. The collecting was done rapidly and with embarrassment if there happened to be people around. Each time the colours were collected, a white and a black piece of paper was scanned as a reference, both at the beginning and at the end of the collection. This is not really enough for calibrating the colours afterwards, but it helped check any major problems with the collection. Next, I will describe shortly each site where the colour collections were created (see Figure 34). As mentioned, I intended that the colour collections would stand as the primary material gathered from the sites. This is what the tool, in its final iteration, is meant to achieve. To this end, also the textual descriptions merely describe the overall situation and do not attempt to convey the site in detail.

[9] The trip to the north was facilitated by the Barents Arctic Network of Graduate schools, and took place in the summer of 2010.

THE KIRUNA MINE

The Kiruna mine is the largest iron mine in the Nordic countries, where mining activity has left a huge trace on the surrounding environment. The impression was that apart from the mine itself, which is very visible, mining industry has also had an influence on the design and architecture of the local built environment. The guided trip took us, the group of visitors, deep below the surface of the mining site. An expectation was that subtle variations of stone colours would be present and could present a nice target for the tool. The walls were then chosen as main source of colours. The mine also presented a clearly delineated space, with the mine walls as the inescapable limits of the design experimentation, reinforced by the guide who would not permit people to stray too far from the group. The device was used in the mine, in an area permitted for visitors. The resulting colour palette is a set of modulated dark greys.

ABISKO RESEARCH STATION CAFETERIA WALL

This colour collection was made from a single object, a wall panel decoration in a cafeteria, made of pieces of bark. The wood in question was birch, with its familiar black-on-white patterns. Here the wall had wide varieties of white and grey modulated towards pinkish red, green and blue, a challenging target for the device, which I already knew to be inaccurate. As envisioned, the device could not capture the subtle differences, and instead all the colours in the collection appear to be skewed towards red. Possibly the lacquered surface reflected back some of the light from the device LED lamps themselves, or the casing could not prevent tiny amounts of external light from entering the sensor. I would wrestle for some time with myself on whether I should see this result as acceptable. The colour collection is an inaccurate representation of the way the colours appeared on the location, but this distortion can also be seen as a tool characteristic. The colour collection becomes the material I'm left with.

THE ARCTIC MOTEL COTTAGE

Here the collection was prompted by a more random occurrence. The site is a motel cottage in Kautokeino, where the trip group stayed overnight. Upon entrance, a moment of solitude provided an opportunity for testing the tool in the inside of a conventional room setting. The motel room is a commercially, if informally designed interior space. These colours of the palette were selected from the painted surfaces of its interior. Variations in textures and glossiness of surface prevented the device from collecting colours in any uniform way, but the collection does evidence a wide variety of strong colours that were present in the environment. Here the collection mostly resembles a conventional designers' colour palette. It is made out of artificial interior elements and everyday object surfaces, a choice which has been previously made by the people who had furnished the interior.

3.3 Tools as design generators

As with the first case, tool making was complemented and followed by review of literature. Whereas the first artefact was coupled with discussion on perception and space, here the topic is directed toward understanding the tool case in terms of design moves. Design studies provided terminology and concepts for interpreting the activity that was happening around this one design case. The overview in the introduction chapter concluded with the notion that this thesis focuses on generative moves as they are played out in reflection-in-action. This theme is expanded on from here, suggested by the experiences of making and using the artefact. Generation is seen from the perspective of a designer who wields tools and concepts that forward the design. The interpretation of the artefact and the resulting insight is derived from the literature. In my practice-led approach, the tool building has preceded the theoretical interpretation and the literature review. The work on and with the artefact provoked this particular direction in literature to explain the activities and moves made during this case. In combination with the artefact description, the chapter is also an elaboration of the theoretical background in the entire thesis.

Design theory and generation

As with the first artefact, steps leading to the formation of the device have been described. The intent was to give a clear picture of how the tool as a design outcome came about. This was then followed with experiments where things were viewed through the lens provided by the tool. To aid in interpreting these major moves, a few concepts from design theoretical literature have been found relevant.

A primary generator (Darke, 1984) is a central design move which makes design manageable but also significantly opens up the creative options for the designer. In the proposed model, a designer is seen to generate, conjecture and analyse, in roughly this order. At the early phase of a design process, architects were seen to narrow down the range of solutions by establishing an initial concept. The concept that produces the solution would be called a primary generator. Darke notes that the architect does not model the design problem as a set of requirements and constraints, but gains a "way in" into the problem through concept definition. For architects, finding an expression for the site is cited as one possible generator. (Ibid., 1984.) The idea of a primary generator resonated with my experiences so far and it made sense to explore the design literature discussing generation and related concepts. Although my interpretation of the theory suggests a tool could on occasion act as a primary generator, the concept more accurately describes a larger motion that becomes acted out differently in particular design cases. Therefore it does not alone work as an interpretation for what the design tool does.

Another key text is Herbert Simon's *Style in design* from 1975. Some parts of the article is reprised in the Sciences of the artificial (Simon, 1996, 129–130), a better known text. In the original version, Simon appears to show more concern than usual towards the exploratory qualities in art, design and architecture. Creative design is not a matter of optimizing the outcomes according to some well defined need. Simon ultimately argues against optimizing, suggesting "satisficing" as a more pragmatic term. Simon's argument is that if it were possible to definitely optimize the whole design outcome in some absolute, quantifiable terms, all designing could be automated. This does not seem to be really possible, and it would also remove all creative elements from the

work. Perhaps vast sameness would also be propagated. Yet, satisficing is not about getting to the point where the design just barely fulfils its function. Simon's point is that there are a vast amount of different designs that can be good or even excellent answers to the initial problem statement, without there being any way to rationally select between the options. It is often in this sense an architect or an industrial designer gets to exercise creativity and inventiveness in the use of resources. An individual free-lance designer may be burdened by even more freedom, as there may be no brief to bound key aspects of the design.

To explain styles in design, Simon proposed an abstract model of creative design as combination of a generator and a test. Initial design propositions can be made relatively uncritically from some basis, but become subjected to a test which filters out the less promising directions. Some of the generators may also be known to satisfy design constraints. Simon proposed that style in architecture would emerge from the way this apparatus is built. As an example, Simon suggested that designing houses from "inside out" or from "outside in" would produce different outcomes (Figure 35). In both cases, the test might still be similar, such as the requirement that the resulting house meets some criteria. Simon speculated that the difference of approach could be deduced from an outcome, such as that high outward symmetry in the building would reveal an outside-in attitude in the design. (Simon, 1996, 128-130.) This illuminates the idea of style emerging from a decision, habit or a belief, as the example is not dictated by materials.

The generator-test model may be interpreted in various ways, depending on how much emphasis is based on the rigor of what is called the "test". In individual art and design activity, the generator and the test may be applied nearly simultaneously, and the test can relate more to the

Figure 35

designer's personal beliefs and artistic credo than to the objects of the design task, and not necessarily consciously. This is acknowledged in Donald Schön's concept of reflection-in-action. The designer may be able to produce material that is useful in forwarding the design, without being able to rationalise these moves. In subsequent reflection-on-action, previously acceptable past work can be seen as failing the test. This can eventually lead toward better articulation and consciousness of the criteria, i.e. reflection on why the work is unsatisfactory.

It seems appropriate to call moves generative, when it is clear that the meaning of the produced thing arises only after it has been made. The probing moves in the designer's reflection-in-action can be in this sense generative. The sketcher's pen leaves traces on paper, potential directions are explored in discussion, material components or visual imagery are juxtaposed. These actions are not the sort that can be immediately justified, but are excursions into what can be. They may be guided by anticipation and a feel or a knack for fruitful and purposeful directions. A designer can be on the lookout for something interesting, original or provocative, depending on the credo. Looking from this angle, tools and building of tools offer opportunity for both giving an initial direction to the produced material, and the varieties of outcomes from the tools. As has been previously discussed, operations on materials and concepts can be tried out without clear expectations on the outcome, such as the inversions, combinations, mutations and analogies mentioned before. These generative moves may be pulled off without foreknowledge of the results success in regard to the test. If the moves are based on a feel of a promising direction, the criteria may not reveal themselves during reflection-in-action. The test criteria as it relates to satisfying an artistic credo, is not likely to be explicitly known.

Nigel Cross has further elaborated such moves as underlying the "creative leaps" (or bridges) in design. A move that provides the key towards a satisfactory design solution then appears as a major creative leap for that particular design task (Cross, 1997). Design moves would vary from a probing exploration to the creative leap that at least in retrospect appears to have solved a major dilemma or show a way out of a stagnant situation. To a degree any such move is detached from the logical assessment of the overall problem or outcome. But as the move is being made, its potential, as regards a sought outcome or as a promising direction is assessed. For example, a piece of paper might be cut to produce shapes and forms that only later become intentional components in space or form making. The suspension of expectations towards the design task as a whole, when making these moves, is what in my interpretation implies a generative attitude. I would also stress that it is not the number of outcomes or ideas produced that defines generative activity. A single act, having a single outcome, can be generative in this sense.

In the case presented in this chapter, various ideas stemmed from the initial choice of the colour sensor. Putting it inside the arrow-shaped container was meant to give direction to the initial ideas, yet with the expectation that a number of routes could still be undertaken. What followed was an exploration of possibilities for the device in that shape. The tool in turn was a candidate for ideas about computer environments, a sketching aid, and in the end, a colour collector. Only the last direction was seen worth while to pursue further, whereas the sketching route held promise but was not seen as fruitful to explore through this tool. To an extent, all these actions were done in the generative mode, searching a route to the greater promise of more varied or interesting outcomes. The tool provided an opportunity to explore ideas that were personally novel to me. The

criteria then was an expectation that any further direction would result in novel uses for the tool in relation to what was already done, but also that the exploration itself could be renewed and sustained. The first choices and the exploratory move-making do not dictate the course of all following design in a machine-like fashion. At every juncture, there is a possibility to put the approaches and the done work to the test.

In the above I have used an interpretation of design generation to describe design explorative activity. Design theoretical literature offers terms and concepts with which to describe a variety of moves that take place within this domain. Design skill can be partly termed as the capability to wield and put these moves into play. The idea that a reflection on a design case advances one's capability to design is in accordance with Donald Schön's idea of a reflective practice. The major expectation was that when building a design tool, the ensuing reflection would be directed towards design activity. By building and using a tool, design activity would become more self-conscious for the purposes of this one case. The view here is that the designer cultivates a personal set of beliefs and a repertoire from which statements and design guides emerge or are drawn.

Problem-mapping versus generative moves

The generative interpretation of design is in contrast with an understanding of design where the designer attempts to map the complexity of an existing situation to project changes to it in order to predict how the proposed changes would affect the situation. The design methods movement was the strongest advocate of this idea, and in a sense, it emerges from a critique of the kind of view examined here. Christopher Alexander, in *Notes on the synthesis of form* (1964) proposed that the design problems could be described in set-theoretical terms that permit exploring possible solutions in terms of their fit. Alexander derides the artistic design approach in an industrial context, as it does not guarantee a good fit between the solution and a problem. In Alexander's view, the artistic designer merely organises the process according to his or her own conceptualizations. Architects learn to avoid the burden of decision by relying on rules and general principles, "the root of all so called 'theories' of architectural design" (Alexander, 1964, 62). Real design problems were seen to be a conflict between requirements and goals (Alexander, 1964, 3), which needed to be mapped and negotiated. Alexander perceived the complexity of architectural design to be outside the scope of what an individual could achieve, and in this light the designer's supposed problem-solving capacity appeared questionable. Whereas difficult mathematical calculations can be facilitated by pen and paper, design problems when framed as conflicts have no obvious symbolic representation. Alexander attempted to transfer from logic and mathematics concepts he felt would be helpful to design, not as prescriptions but as a means for supplying useful devices for organizing design. (Alexander, 1964, 3–8.) As Gedenryd notes, the design method movement in its more ambitious form came to be abandoned rapidly, most vocally by Alexander himself (Gedenryd, 1998, 59–60). What followed was not a full re-embracing of the intuitive ways of making, but an attempt to understand how designers and architects really work.

Curiously, Alexander in his early work is able to describe the intuitive design approach quite well. The architects construe their own world view and deploy invented organizing devices drawn from a repertoire of existing means. They derive outcome exemplars and ways of acting from magazines and through emulating their masters. To him much of what passed as architectural theory appears as a "result of arbitrary historical accidents" (Alexander, 1964, 65). In the criticized idea of intuitive design, the designers resort on conceptual devices rather being constrained to objective factors of the real problem. This was also largely what Darke observed architects to do (Darke, 1984). The idea that architectural theory books do not supply actual theory is in some respects true. A book on architectural theory can describe what instead appears as movements, and look back nowadays ranges from functionalism to green architecture (e.g. Mallgrave and Goodman, 2011). This does not diminish their significance as they are contributions to the culture of architecture, feeding the personal theory bases from which decisions and moves become acted out.

The way Alexander initially attacked the old fashioned design already contains the critique toward the view of design as, generative process guided by intuition. Unjustifiable moves can appear frivolous, if the intent is to produce provable improvements or problem solutions. One possible resolution is that even in the context of rationally organized design generative moves are needed to open up directions and propose alternatives. Not everything made during the process can be justified as directed toward the goal, much as the searching lines in a sketch do not all contribute to the final appearance of a painting. This resembles Michael Polanyi's (1966) argument about tacit knowledge as it relates to scientific problem solving. Although problem solving has

a logical and rational component, the way the problem becomes recognised in the first place cannot be put in these terms. (Polanyi, 1966, 21–23.) This would justify the seemingly irrational moves that are made in attempt to probe the problem. In this view, then, the discussion on generative design moves only pertains to these parts within the process, and the skilled application of these moves may be examined in isolation to the ends to which they are put. Trying to shoehorn ideas about causality and rationality to individual design moves may be ill-advised

Generative moves in the personal repertoire

I will now further elucidate on the role of generative design moves as components in a personal theory. Schön described the practitioner's repertoire to include "[...] the whole of his experience insofar as it is accessible to him for understanding and action". From past experience, the designer recognizes familiar situations for courses of action. These are not simply rules that can be applied to a well understood situation, but exemplars that can also have bearing on a largely unfamiliar situation. (Schön, 1991, 138.) This also includes approaches and methods that are more artificial creations. Simon's suggestion about the origins of styles residing in a generative apparatus in art, as explained earlier in this chapter, can be taken as a starting point. Although good for illuminating a principle, the generator-test model is too limited a device for fully explaining the design processes, which reside in more complex cultural surroundings of the professional design world, society and education. One may ask if Simon's "two schools" of house design are even real options. Do the labels of inside-out and outside-in denote an identifiable, recognizable design approach that would be even roughly similar between two people who both claim to subscribe to one of the views. It is possible that if the designer has not established for himself such a method or a principle from which to draw from, then the words may simply act as generative metaphors. In this way, many imagined sensible combinations of the approaches would be available to a designer, depending on how they become played out. The two schools presented by Simon are not really only about applying a mechanical generator to the task of producing building form, but labels for genuine approaches that need to be learned. This is probably why, for example, Bryan Lawson puts emphasis on devising guiding principles and design strategies as part of what designer does. The designer builds a consistent world view from which the design strategies and principles are drawn from (Lawson, 2006, 159–198). The place for generative moves would this way be found in a broader setting.

Art history and history of architecture seek to trace past influences and how they manifest themselves in outcomes. Architectural history can be especially helpful, as the history is long and the examples are known and documented. For example, the burgeoning modernism in Finland has been described as a project of finding appropriate form for national romanticist ideals, by exploiting locally available granite (Frampton, 2007, 193). The art historian Sixten Ringbom traced the ideology of truth in material, the notion that building construction ought to utilize materials "honestly", to find different interpretations of this idea in each of the Nordic countries (Ringbom, 1987). This indicates more diverse and richer base for the choice of design

moves than the exploitation of material that just happened to be available.

Now, the question whether buildings ought to be designed from inside out or outside in, seems to have occupied a place in serious architectural discussion around the turn of the 19th and 20th centuries. For example, Finnish architect and teacher J.S. Sirén would, in his lectures, offer advice for students grappling with this thorny question: neither inside out or outside in, but both at the same time (Sirén, 1977). Just as with the use of granite material in Nordic countries, this issue has complex roots. Rinbgom notes that 19th century public and professional discussion on architecture nearly always revolved around the façade. Even professional technical literature would transmit new architectural ideas primarily in form of façade drawings. According to Ringbom, modernists relegated the façade to a secondary position, favoring instead an understanding of the "spatial structure" as the primary object in architecture. (Ringbom, 1987, 10.) Broader ideological forces were at play than a question of inside-out or outside-in. Prior to 20th century, it might not have been an option to think of the two directions as purely style-generating, as it was for Simon more than 50 years later. The choices to identify space with façade or spatial structure relates to what the community of architects believed to be valuable, interesting and worth striving for. To use Schön's terminology of task or role framing (Schön, 1991, 310), the practitioners in the architectural profession had not at that time framed their tasks in terms of inside-out or outside-in, as was later possible for Simon. Instead, they acted from within a role where the view that façade equated to building art was a given. Modernist architecture dwelled on the relation of the interior and the exterior, deliberately confusing and questioning the border between the two. Disparate and even conflicting architectural theories, more likely personal

credos and ideologies, can be interpreted as possible alternatives available to the designer, just as the choice to design a building from inside out or outside in.

The above has discussed the ways design tools and conceptual moves might find their way into the designer's personal repertoire in a larger setting. The issue of how tools and "design moves" relate to ideological streams within a profession or culture at large leads to themes outside this thesis. Yet, by referring to a historical example, I have sought to demonstrate a possible role for both material and conceptual devices within a broader panorama. The inside-out or outside-in may be a simple summation of a complex discussion that was at the roots of the transition from classical to modernist architecture. Actually learning how to design from inside-out would be a matter of "getting" a mode of approach, possibly learned through education and examples set by more experienced practitioners.

Summarizing the literature

The design literature has offered a model for seeing tools and artefacts as source for generative moves. The generative interpretation of design action puts emphasis on the fact that design moves and proposals are made without explicit guarantee of their relevance to the overall process. The designer, in learning these moves can add them to his or her personal repertoire. Some of them may be supplied by education and examples set by others. Through my work, I have been suggesting that the choice and use of tool can set a design direction as can a conceptual move. Both play itself out at the formative phase of any design. This would give

credence to the idea that building tools allows access to reflecting on these moves.

In the above review, I have also attempted to identify some boundaries for what can be achieved with understanding design as a generative activity. I provided a glimpse to how the design approaches can be related to a wider discussion that fuels the repertoire building of the designer. It may be that the choice of approach is not a mere happenstance or an isolated personal exercise for the designer. Otherwise the generative toolbox would remain a fairly superficial and technical device which it may have appeared in some examples. Beliefs, such as those of "national expression", "truth in material", "design from inside out" all have intricate relations to the world and context in which they originated. They are also summary statements from which a new ideology or design guideline might be re-built differently, as the original movement has passed away. The concept of generation collects together the ways material design tools can play a part in core design activity, as conduits and carriers for exploratory acts. A tool object can produce a transformation or a view to the design matter that can be described as a generative move. The results are not necessarily novel, surprising or insightful. It is just that the moves are made on a hunch and anticipation rather than a clear expectation or a guarantee. The designer judges whether the tool outcome or the view it provides to the design task appears productive towards the pursued ends. Building one's own tool is to have a similar anticipation towards outcomes of the particular tool.

3.4 Closing the case

The chapter has presented a history of designing a hand held tool. The tool was purposed for two distinct roles. The first purpose was to extend the colour scope of a computer sketching situation for two-handed, skilled operation. The second role of the tool was to implement it as a conceptual limiting device in building colour collections out of a site. The chapter has set focus on the generative design activity that emerged during the building and use of this second artefact. This thematic arises from the combined activity of building, trying out the artefact and reading the literature. But it can also be related to a specific memorable event that left certain questions hanging for a long time. This event, as reported above, was the failure of the tool and the subsequent compensation strategy of executing the task by hand using watercolours. This put the motive for making the tool into question. The idea of selecting a very narrow aspect of the site appeared as a more significant interest and possibility than the actual tool that it was executed with. The building was necessary to arrive at this moment of reflection and the questioning attitude. Overall, the things done necessitated an articulation of the personal design intentions underlying the tool and its uses.

When building the artefact, a single driving idea was not consistently present throughout the case. Instead, the material object helped keep the case together. The initial idea to parody computer desktop environments fuelled the building of the tool at the first stage, but was found to be uninteresting in terms of actually making a tool. The explanation for abandoning a direction is found not in the practical viewpoint but by identifying the point where the direction begins to divert from the intended brief the designer has set. Personal beliefs and interests drive and guide the selection. Generation may be relatively uncritical, but the test, where candidate ideas are culled out, is also determined by these

beliefs. Having added the generative moves to his personal repertoire, the designer may put them to use. Although the generation itself may be uncritical, the selection of a generative method and the appreciation of the outcomes are both subject to designer's evaluation.

Building the tool as an articulation of design

After the experience with the first artefact, I was already open to the possibility that making the device would be merely the next step in building my understanding about design. I started with an assumption that a tool in design is unlikely to be a simple intermediate layer between the person and the thing to be created. The things produced during designing become "tools" in themselves, suggesting ways forward. I have sought to collect various design moves under the banner of design generation. In this thesis, the ways, mediums and materials that permit such generative moves, are called design tools. In this interpretation it is not, for example, the mode of representation that defines the tool but rather the way it is put to use. In this second artefact case, sketches and drawings had little role in forwarding the design concept in any major way. I instead see the different tool variants and alternative routes as the most significant junctures in this artefact case. The work on the artefact and its interpretation have helped to arrive at this idea of a design tool for the purposes of this thesis.

The objective was to primarily design the tool to address the research questions, and not to design something else

through using the device. On the one hand, the device is an object that might have bearing on some future design. The colour collection example was used to demonstrate how the device could be used to achieve a rudimentary conceptual move, producing a colour set out of the site surfaces. The decision to use the tool as a way to transform collected values from the site into a picture of the site is a design move. On the other hand, the object is primarily a research artefact. After the colour collection was achieved, its significance for some further design goal was no longer discussed. In this sense the artefact is nearly not a design tool at all. It is meant to allow a way into the topic of generative design moves and to forward reflective thinking. The various exploratory directions taken show the research in process. These two roles become intermingled. In my interpretation of a practice-led approach I have allowed initial uncertainty, even simple-mindedness into the design stage, as long as the project moves in a productive direction. The process around the second artefact is especially free-form, with each successive finding or stage suggesting something else.

With this artefact, the practical design work has indeed "led" the research. Yet this has not happened haphazardly or mindlessly. Firstly, the overall research topic had from the first been established as visual, conceptual design tools. The question was how design tools can be built by designers and how this self-building might benefit them. These themes kept the process together, even as the focus shifted more towards identifying personal theory elements and generative moves within the journey. Secondly, choices between alternatives during this design journey have not been made randomly, but with some expectation or anticipation of what might result in an interesting outcome in relation to the first artefact. This is the driving logic behind both the design and research sensibility. The designer in me wants to pursue

something novel and challenging, whereas the researcher-side expects rich material and counterpoints to emerge from the undertaken journey. In the first artefact case, the visualization had become a very definite object through making it as a computer program. Only afterwards the question about its implications was raised. Although some directions were examined by making further programs, these turned out to be unsatisfactory and laborious. In the second artefact project, it was recognized from the onset that the device could serve many purposes, before reduction to one definite use. In this way, interest and exploration could be sustained until more promising angles emerged. The device might still be repurposed in the future.

A convention in practice-led and design-oriented research seems to be to offer insight into a single case and its iterations, or exhibit a fairly consistent oeuvre of similar works. At this stage, I have brought forward two different artefacts. For the purposes of practice-led research, I see possibilities for examining movements and motives between works that are clearly different. The reflection provided by one artefact case becomes eventually exhausted. To reflect more distinctly on the angle of making, new material was needed. Still, the work on the second artefact was not done in indifference or isolation towards the perceptual topics opened up in the first chapter. Specifically, the first artefact established an outlook into perception and space. This perceptual outlook was a spatial conception that underlined the eye-level experience of interior space as an opening and closing of vistas. What has been left out, were other significances that may be associated with places. Although the perceptual considerations did not turn out to be as crucial for the thinking in this second case, the initiation of the case is also a motion or response to the first one. The first artefact was prompted by a discussion on conceptions of space and ways a tool might begin to frame space for design purposes. Although it is possible to see the second artefact as an emergence of a new spatial conception to the design repertoire, one that is based more on physical presence, touch and body movement or even colour than space, the second artefact has been more significant in shaping an understanding on design. Unlike with the first artefact, the work is not so much about a conception of space, but conception of what it means to design, particularly, when the more generative and exploratory is given priority. The ability to produce proposals and alternatives should be relevant also in problem-oriented design, although this proposition has not been explored here.

Here the process was a cycle of constructing, discovering new avenues and possibilities all emerging from a project to build a single tool. As was seen, some of the ideas which become suggested by the tool did not ultimately require the tool itself. The concept the tool stands for becomes clarified through establishing definite rules that the tool enforces. Yet as these self-imposed rules become understood, the definite rules become abandoned in favour of a more organic approach towards the tool use. The artefact breakdown was a singular event that provoked much retrospective thought. It is what Schön termed as a surprise moment, an exceptional occurrence that provokes reflection-on-action, to explain the anomaly (Schön, 1991, 153). The concept of the tool helped form the lens for looking at my whole activity during the thesis project.

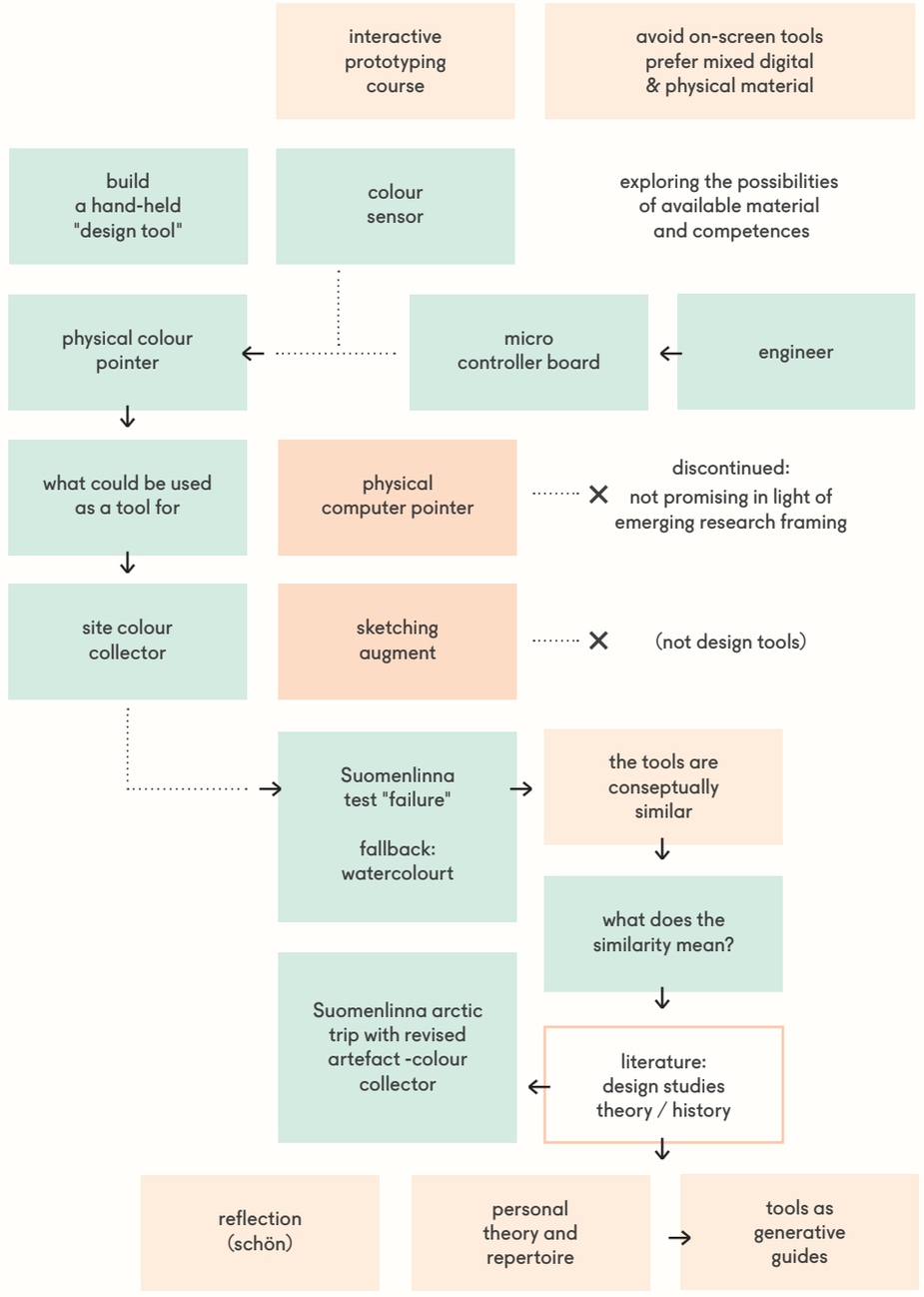
This artefact case has been used to describe both a generative impetus within the tool building project but also the use of the design tool interpreted as a generative move. Initial choices in a project become crucial. Exploring the possibilities of the colour sensor gave the most important definitions for later stages in this case. Testing different uses

for the tool brought a variety of tool concepts to the fore. The brief and research questions keep the different directions in check, and the tool became settled as a colour collecting device. Conceptual generative tools and organising devices are just as potent materials in this kind of process as are the physical materials. The second artefact case represents a more conscious use of the practice-led approach that had occurred with the first artefact. The device was built with the expectation that the resulting experiences could be connected to literature. Unlike with the first case, there was no immediate visual shape that would have helped find a connection between the tool and a theoretical topic. This time, an idea of what the tool represents had to emerge as a concept, which then could be compared and contrasted with concepts and theories in design literature. The concept of generation had remained in the fore after the experiments with computational approaches, and the computational understanding of the term was still influential.

The activity suggested that making a tool can help reflection on personal theory building and an articulation of how I understand design to be. The view on the way design proceeds, and reflecting on this view, came to be highlighted through making this object. Choices suggest further possibilities, like putting lines on paper can be diverted to different streams. In this view, the materials in design may be used without at first meaning or intending to simulate, map or communicate. Mastering how this field of materials and concepts can be manipulated is a skill into itself. What designers do is not achieved only through concrete tools, but also a conceptual apparatus where the tool and the design to be tooled are not always separable. Not only material work, but ideas and actions become suggested and thus also "generated" during the design process. This kind of apparatus cannot be diminished to "just a tool", as it can imply or

Figure 36 (p. 141)

Map of the second artefact case progression. The origin of the device is in an interactive prototyping coursework, which shaped the initial brief for the project. The provisional practical questions lead eventually to the creation of the "generative" and "personal theory" lens as major explanations and conceptual tools.



carry with it a more deeply rooted ideological basis. Especially this can be true with a self-built tool.

This chapter has described the building of a tool and opened up the conceptual frame of the thesis. This was achieved by connecting the tool theme to concepts found in a more general theory in design. My understanding of design moves is also built alongside and demonstrated in the description of building the artefact. The conceptual moves and generative activity mostly fit into Donald Schön's concept of reflection-in-action. Not only sketches but situations "talk back", and are progressed forward with moves and approaches in the designer's repertoire. Tool-building has been presented as a way to enhance my reflection on design and to develop my personal theory through further additions to my repertoire of design moves. This resembles what Schön would term frame analysis in a professional context, a way to identify and question the way problems and roles become framed within the profession. (Schön, 1991, 310–315). Tool-building was not explicitly mentioned by Schön as a means to achieve analysis. My impression is that this angle ought to be intriguing to practice-based and research-through-design approaches in the design field, both as a repertoire-building activity and a way to examine one's way of designing.

One of the exploratory directions brought design drawing and sketching to the fore. I had intended to examine something more close to design drawing when the issue emerged. Design drawing, as a topic, allows numerous windows to examining design generation and conceptual tools. It is a means for envisioning potential forms and outcomes. Therefore, the next artefact addresses modelling and drawing, but also extends the reflection on the building of a new artefact. The next case puts together much of what has been worked on in the first two artefacts.

Drawing surfaces

Figures 37–53
56–58
60–69

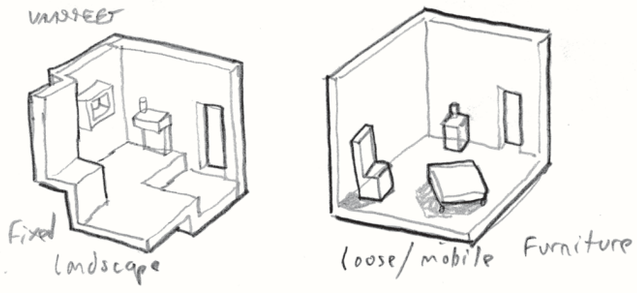


Figure 37

Sketching a concept visualisation for a room. A project assignment to study small apartment concepts provoked sketching on the topic. (Author's sketch, inferred date: January/February 2008.)

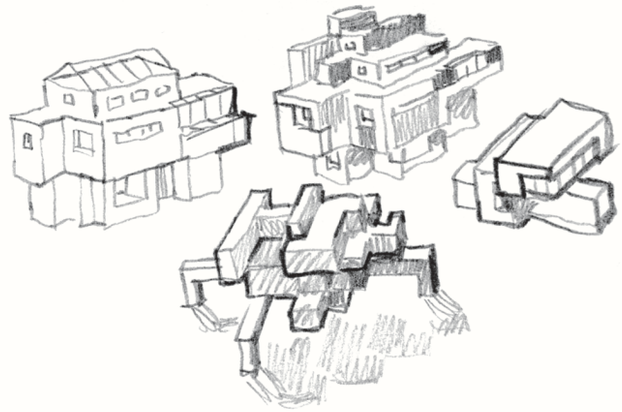


Figure 38

Doodles of buildings. (Author's sketch, inferred date: January/February 2008.)

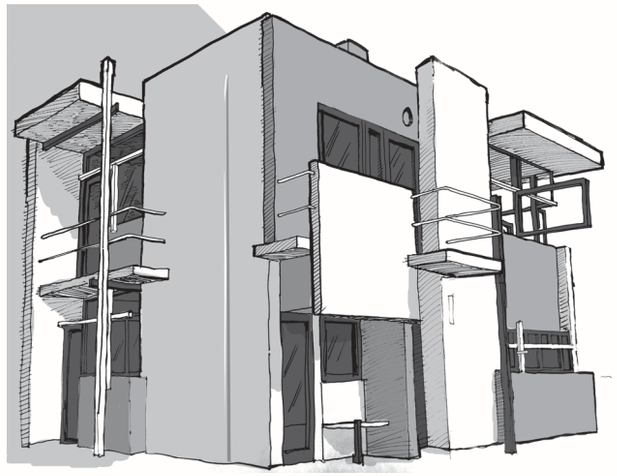


Figure 39

Gerrit Thomas Rietveld: Schröder house (1924). (Author's drawing, 2012)

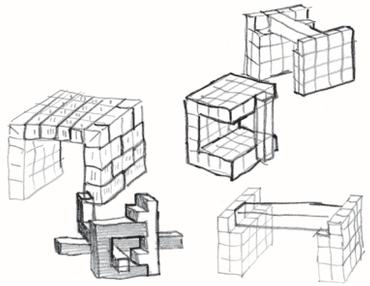
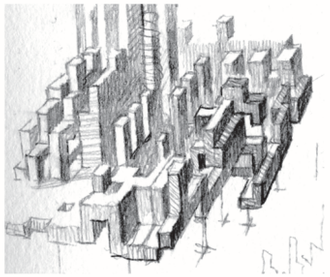


Figure 40

A sketch for examining tiles as basic blocks for building form. (Author's sketch, inferred date: January/ February 2008.)



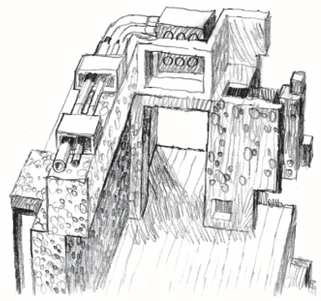


Figure 41

Left: Author's sketch from the first quarter of 2003. Right: Author's sketch from the beginning of 2008, before making the first functional version of the software. The program was made in hope of being able to explore this type of form more effectively than possible by drawing. (Undated author's sketches, dates inferred.)

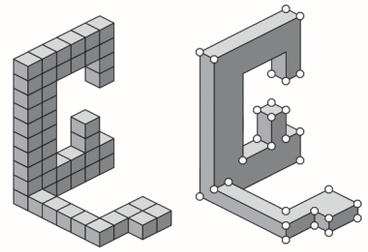


Figure 42

Left: Tile-based modelling with volumetric pixels, voxels. Right: The same shape with conventional, surface based modelling. This usually implies control points at the edges as the easiest way to modify the existing shape. With tiles, the shape is defined by setting spatial cells on and off.

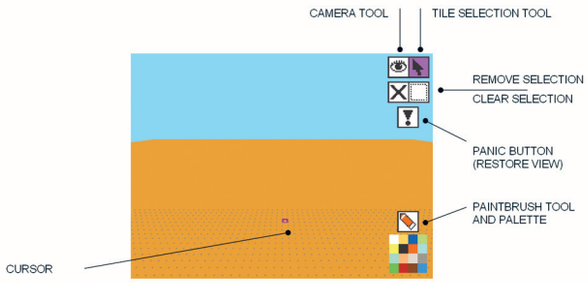


Figure 43

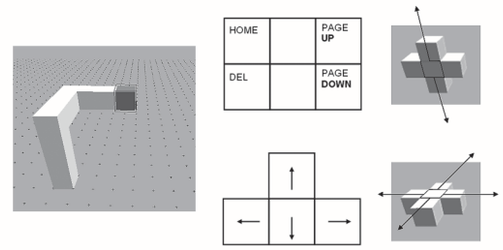
The opening view to the tile modelling software and its basic options. The software gives a flat tiled landscape from which to begin working.

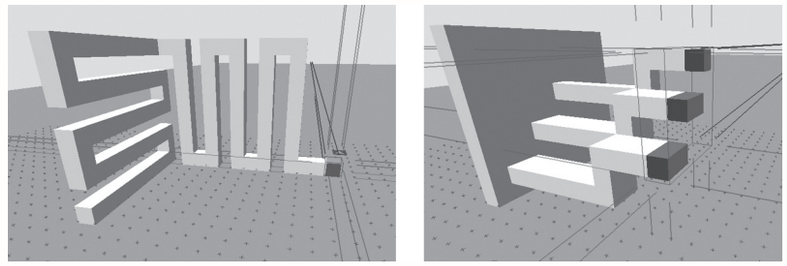
Figure 44

The basic concept for the software. Arrow keys moves the cursor on the horizontal plane, relative to the looking direction. Page up and page down keys are used to move the cursor up and down in space.

Figure 45

The two varieties created for collecting the outcomes. Left: Single cursor incremental, where larger wholes have to be construed by moving the single cursor, the dark tile. Right: Multiple tiles can be selected and moved freely. The selection does not need to be continuous.





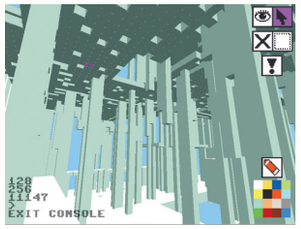
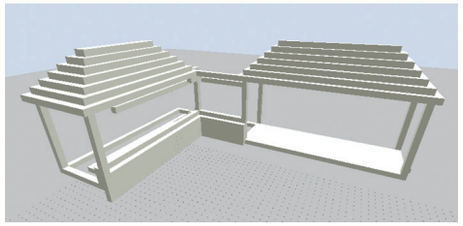


Figure 46

Example of experimental work from the time the software is still made. The shapes result from randomly selected and manipulated material. The outcome space is then examined for interesting views, further edited.



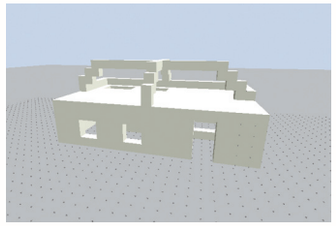


Figure 47–48

The incremental version offered a way to build forms by first creating an outline frame that is subsequently filled. Left: Outcome 12 (Incomplete), Right: Outcome 14.

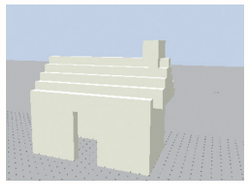


Figure 49

A snow house that was built by advancing one completed wall at a time. (15)

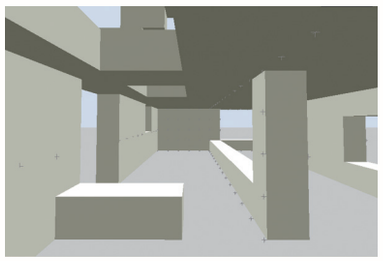
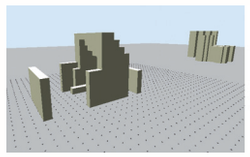


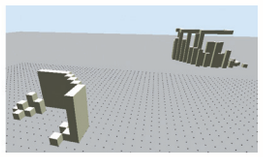
Figure 50

Outcome 14. Here the interior of the model is a partially unexpected outcome from working with the exterior, which is then slightly adjusted from the inside view.

Figure 51

Two examples where the outcome has arisen from considering a protective role in a probable snow ball fight. Left: Outcome 13, Right: Outcome 11. The block piles were said to represent snow balls.





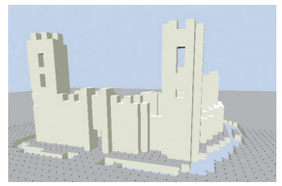


Figure 52

An example of a snow fortress interpreted as an iconic idea of a castle with moats, walls and towers. (Outcome PS8)

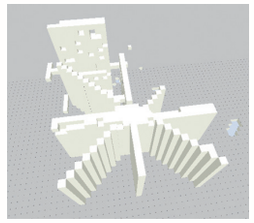


Figure 53

Outcome PS7. The snow fort task is displaced into a snowflake, which is tried out as a building form. (Stated to be incomplete)

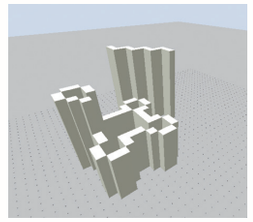
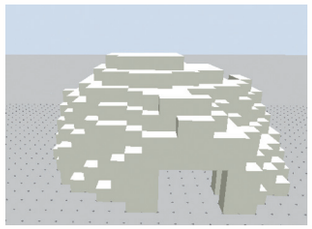


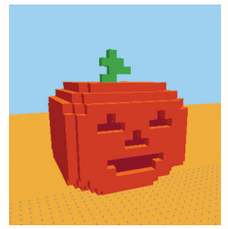
Figure 56

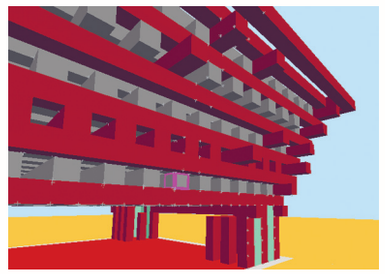
The paint version made it possible to extrude a shape drawn on the ground, resulting in some rather quick solutions. (Outcome PS4)

Figure 57

Left: Outcome PS3. Right: Outcome 121. With perseverance, approximately round shapes could be produced.







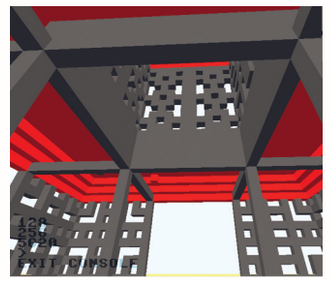


Figure 58

Outcome 123, recreation of the China pavilion in Expo 2010.

Figure 59

Outcome 124. Oriental ornamentation has been a clear influence for the wall treatments.

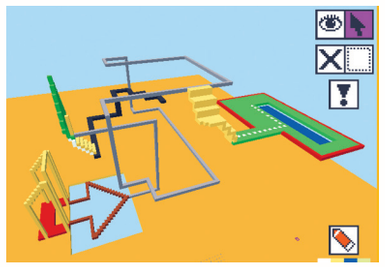


Figure 60

Outcome 122. A model inspired by a television game show. The model combines lines as representing routes, combined with symbolic elements (the arrow and the tree).

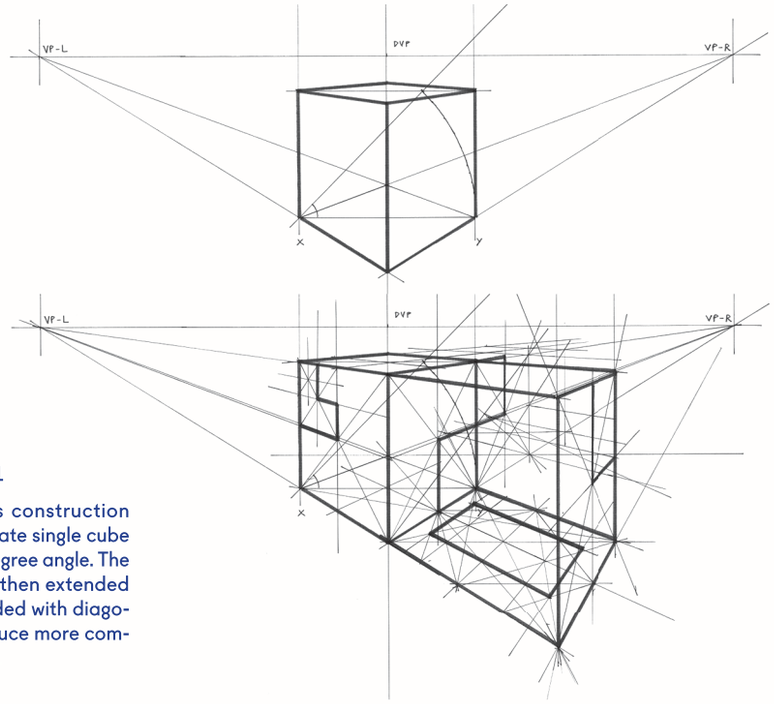


Figure 61

Jay Doblin"s construction for an accurate single cube from a 45 degree angle. The first cube is then extended and subdivided with diagonals to produce more complex objects.

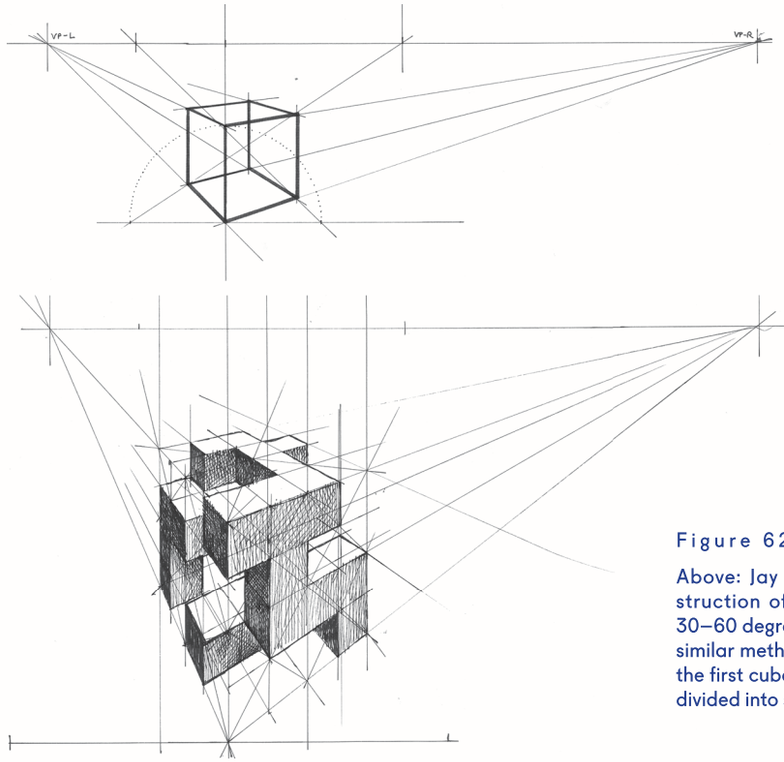


Figure 62

Above: Jay Doblin"s construction of a cube from 30–60 degree angle. Using similar method for drawing the first cube, which is then divided into smaller parts.

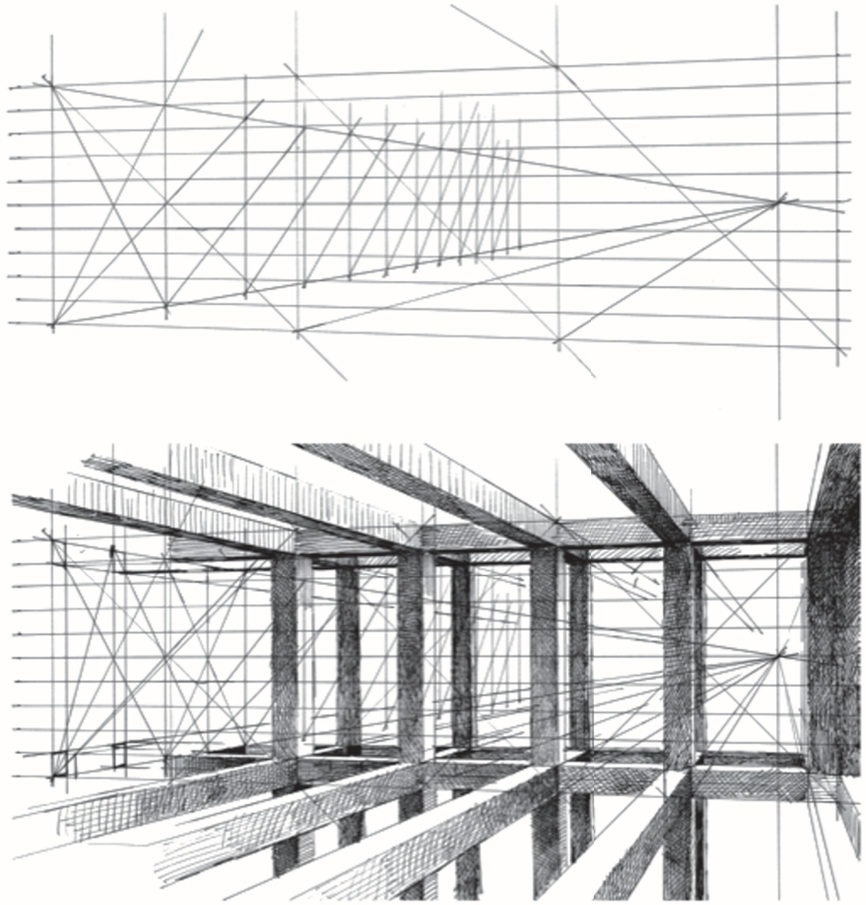


Figure 63

Following William Kirby Lockard's method, the initial geometric planes are established on paper. Above: Setting the depth plane (the wall extending towards the vanishing point) correctly is a matter of judgment. Below: Sketching on the grid. Unpracticed use results in difficulties judging the depth accurately.

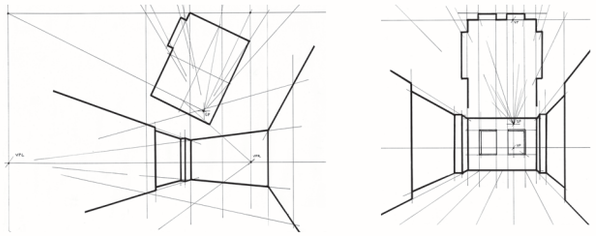
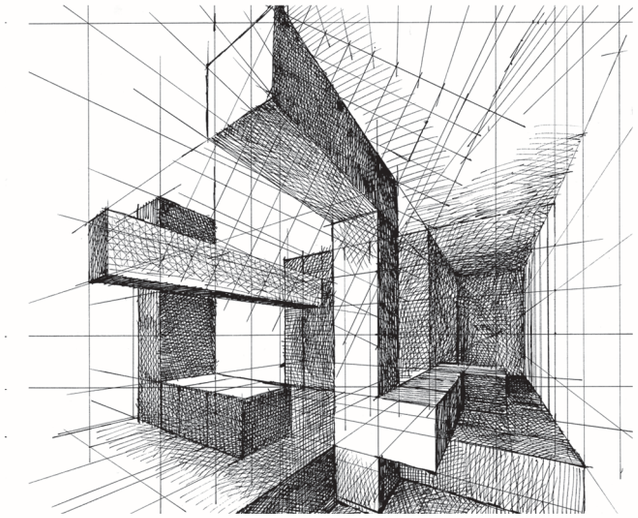


Figure 64

Interior views drawn with John Pile's method. Left: Two-point perspective, the main method. Right: One-point perspective. The imaginary picture plane is made to coincide with the back wall. The sight lines are projected downwards to make the wall verticals.



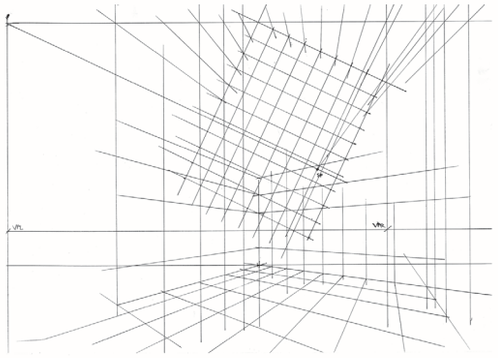


Figure 65

Left: Building a grid box with Pile's method. Right: Extemporising over the drawn grid. (Author's drawings, 15.5.2012)

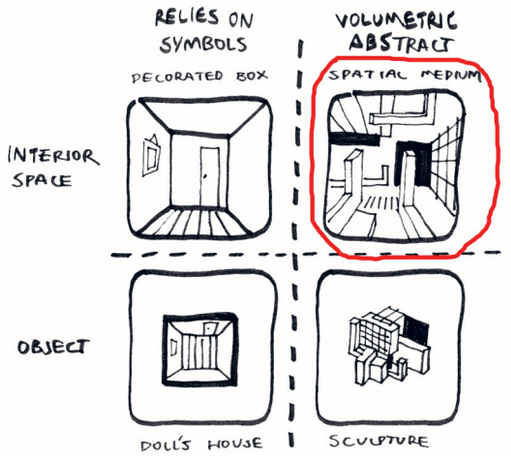


Figure 66

The different tendencies in drawing spaces become identified. The volumetric abstract was considered a goal. Yet all the different directions could be put into use during drawing.

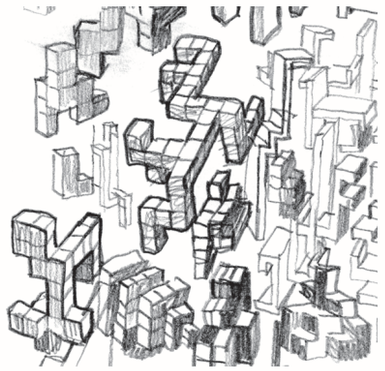


Figure 67

Author's sketches from early 2008. Exploration of the cubic shapes is in full force alongside designing the software.

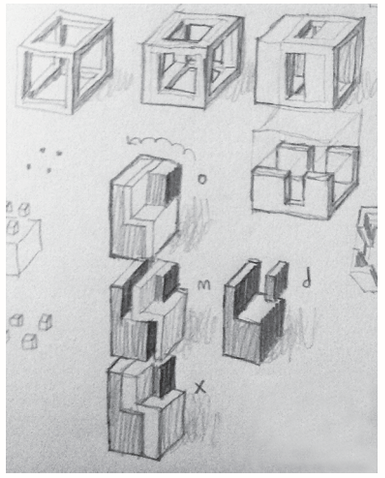
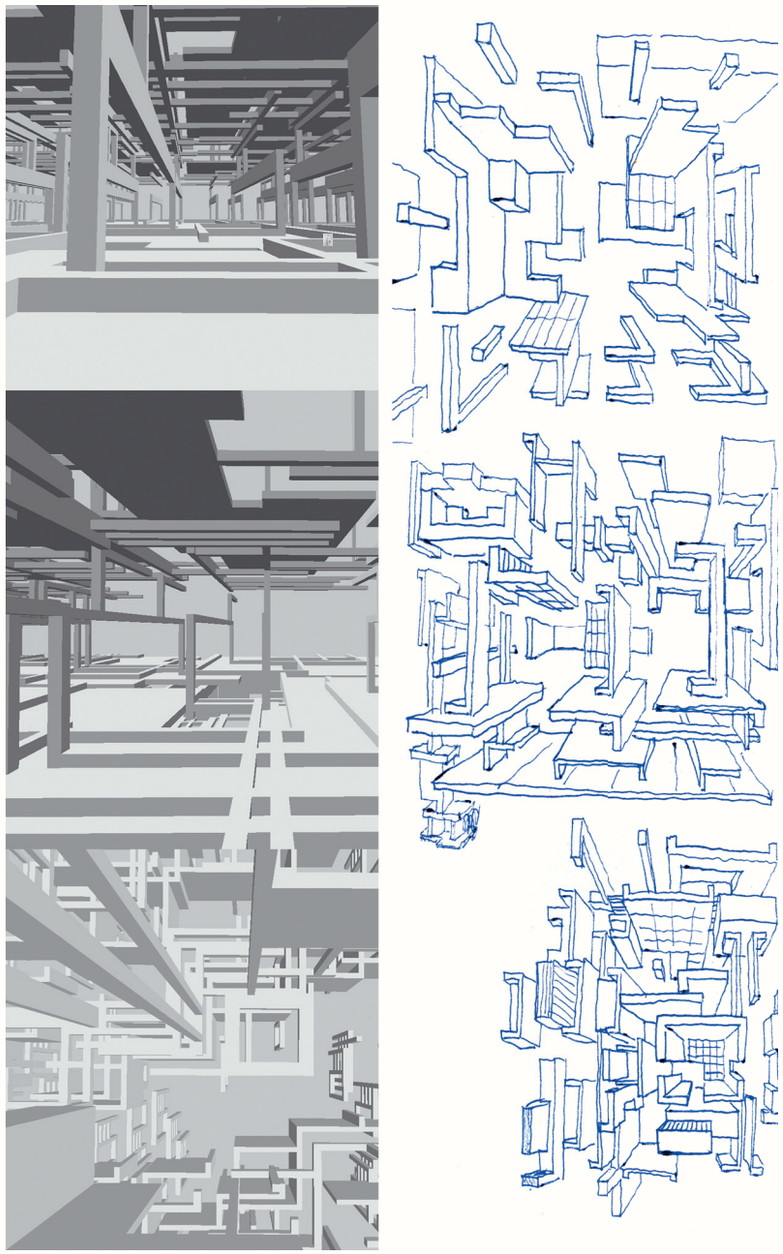


Figure 68

A key sketch made for the purposes of programming. The sketches clarify how the original shape (o) ought to behave when the selected shape is moved (m), extended (x) or deleted (d).

Figure 69

Left: Output from the software, 2011. Right: Ballpoint pen sketches, exploring the frontal perspective without setting up a prior frame.



4. Drawing surfaces

The third artefact case is a modelling software which is based on an understanding of sketching spaces. The assumptions and goals about drawing inform making the program, which becomes one particular way for exploring spatial form. The making of the modelling software is a process which highlights this one way of working with space, turning the reflection back towards the drawing technique. These experiences feed back to the drawing processes from which it originated from. Drawing is examined as one potent means for devising tools. As a skilled activity, it represents the third angle towards building one's own design tools in this thesis. Drawing and modelling are regarded as a material means to play out ones belief and personal theory-building. The tool building becomes a means for extending and articulating aspects of this skill.

"The horse carries the rider quickly and sturdily. The rider, however, guides the horse. The artist's talent carries him to great heights quickly and sturdily. The artist, however, guides his talent"

-Wassily Kandinsky, ***Reminiscences*** (Kandinsky, 1982, 370).

4.1 Premises

Every belief about how to approach a design task is an anchor cast, from which the subsequent exploration stems. Again, it is possible to return to Herbert Simon's example of designing buildings from inside out, or from outside in (Simon, 1975). What would it mean to really commit to either of these approaches? Drawing is one way to play out the choice in concrete terms, interpreting the statement as a way to draw. Multiple interpretations avail themselves to the designer. The drawing can start from a plan view or an eye-level sketch. The starting point could be materials at hand

or imagination. Looking at drawing is one way to interpret Simon's example, as it is a powerful way to explore one's repertoire of design strategies.

The first artefact chapter was concluded with a discussion on spatial conception and framing space according to geometries of vision in perception. Building and examining the visualization was described as a way to reflect on the idea of space. The initial attempts to transfer aspects of the visualisation into tools were unsuccessful. The visualisation was detached from the actual creation of forms and space, which are more clearly traceable in drawing and modelling. The second artefact, the handheld tool, was initiated as a way to address the tool angle within the research project, yet still keeping distance from creating shapes. The previous chapter presented the concept of generative moves, which could be used for both dissecting the design process and seeing the making of tools as a series of interrelated generative acts. Overall, the tool building process made a design credo more visible through reflection. Here the tool-building angle becomes fruitful when discussing drawing. Perspective method is used as an example of design drawing, and three perspective method books are presented. These methods are interpreted as arising from the personal preferences and beliefs of the authors. They are seen as attempts to transmit knowledge in design fields, explicating elements of personal design knowledge, know-how and skill. The perspective methods become examined in terms of practice-led research contributions. The exposition of these methods in the books is one source from which to build one's own outlook toward design drawing.

In this chapter I examine the intertwining of a design drawing process and making a software artefact for sketching spaces from tiles. The building of the software is explained as a way in which aspects of drawing skill and the personal theory of space becomes explicated. Whereas the first two artefacts represented an attempt to distance myself from an overtly familiar medium, the third artefact collects the work together to address design drawing as a way to produce design material. The literature around this case relates to design drawing and especially perspective methods as means to convey ideas about space. This continues within the theme, begun with the previous artefact, of reduction and constraining as a design move. Design drawing and perspective drawings are interpreted in terms of such moves. A drawing style is chosen that allows envisioning shapes directly, leaving out concept sketches or design diagrams.

The move toward drawing

Drawing is such a constant part of the author's personal history, that it would have been difficult to initiate a meaningful drawing project in the first instance of research. As mentioned, the previous artefacts were created with a motive to get some distance from drawing. Yet a more specific interest toward modelling and drawing started to gradually build up, beginning from an initially unrelated project where a more conventional apartment space came into focus[10]. Participation in that project work is not discussed here as a case, but it is noteworthy that the practical context of the project was what brought the design drawing issues to light.

The issues of designing apartment space did not in the end influence the thesis research much, but it nevertheless provided with the impetus to explore the notion of interior space through drawing. This work also challenged the previous artefacts in that it was questionable in what way

[10] The project which explored small apartment concepts was conducted in the year 2008, as part of the project 24Living, funded by participating companies and Tekes, the Finnish funding agency for technology and innovation. Some of the themes were flexible apartments and modularity. The project was conducted in the Future Home Institute research group in the University of Art and Design Helsinki.

they actually contributed to producing design proposals. The abandoned directions that followed the first artefact were attempts to put the first artefact learning into effect in modelling. This was seen as premature, and in part the disappointments with these approaches prompted a return to drawing as a richer environment for exploring spaces. Now it was the drawing technique that was brought under scrutiny. During sketching, I recognized difficulties in articulating rooms and spaces in drawings. In light of the work on the first artefact and the thoughts that arose from it, the drawings started to seem problematic. It seemed that what I now more clearly believed about perception and motion should be reflected in the sketches, and this was not really achieved. The pictures were strained towards depicting structure and conventional elements such as doorways, windows and stairs. Also, even if they were intended to depict interior space, it worried me that they pictured space from the outside. The buildings were drawn as sculptures, viewed from distance. (Figure 37 and Figure 38.)

Figure 37
Figure 38

The dissatisfaction towards these drawings can be put in clearer terms when the output is compared to a design exemplar. In comparison to a well known work, such as Thomas Gerrit Rietveld's Schröder house from 1924 (Figure 39), the exploration of form in the drawing process seemed narrow in scope. In the Schröder house, many modernist ideals are taken to the extreme. The house is a composition that freely extends the geometric three dimensions in defiance of simple functional division. The same geometric and colouring style is utilized throughout the building exterior, interior and furniture.

Figure 39

The Schröder house has been described as a single spatial continuum, with the borders of inside and outside becoming blurred (Sparke, 2008, 175). Much of this has been achieved not literally but through clever composition, and it is the richness of this composition that has fascinated me. The aim here has not been to achieve a pastiche of one modernist style, but to ask what enables one to reach a level in drawing where such spatial articulation could even become possible. The problems in the drawing process become identified in light of Rietveld's building and furniture design work, as a benchmark for what my sketching could ideally achieve.

It has been suggested that Rietveld's three-dimensional spatial treatment arises from model work and furniture manufacture rather than a preoccupation with plan drawing (Overy, 1988, 32–33). It appears common sense that such compositions can be more readily achieved by model work. An attempt to reach similar level of articulation through drawing is a different challenge. Further in this chapter, design drawing books and perspective manuals are seen to address similar challenges. One result of the work on the first artefact was in helping identify clearly the aforementioned problems in my drawing process, helping set up this challenge. The experiences from the first artefact and the subsequent abandoned attempts provide ground for reflecting on the drawing.

Tile-based modelling

Figure 40
Figure 41

The artefact is an attempt to bring the desired articulation of space into a clear outline. To this effect I built software for building shapes from discrete tiles instead of lines. It is difficult to find exact reasons of the choice. Looking at my drawings, the desired outcomes have such geometric rigidness that it is easy to see that cubic blocks would permit exploration of the desired form. In some drawings, I had started to envision the kind of outcomes this type of software might achieve

(Figure 40). One influence was the book Architecture's new media by Yehuda Kalay (2004), where solids are presented as one alternative to the more common line and surface modelling geometries. Kalay describes the tile structure as spatial occupancy enumeration, but also uses the common term voxel, or volumetric cell[11]. To Kalay, voxels are less viable for architectural modelling than line and component geometries. Memory and computation issues prevent precise voxel modelling of buildings. Also, establishing hierarchies between objects and parts becomes problematic, as voxels tend toward homogeneous structure. (Kalay, 2004, 143–144.) Mitchell similarly discusses grid structures in his overview of computer-aided design, noting that inadequate memory capability prevents exploring this type of structure (Mitchell, 1977). Although voxels are much used in scientific visualisation, relatively little has happened in design fields until recently, nonwithstanding the increases in computer power. For example, Sevaldson relates his experiences with voxels and scientific visualisation in the early 90s, noting that the lack of suitable interfaces and the trouble with transferring voxel models to conventional programs prevented him from exploring this direction further. (Sevaldson, 2005, 250–251.)

For me, Kalay's objections and the relative novelty prompted curiosity towards this structure, and any misgivings about its value in an architectural context did not register as an obstacle here. In contrast, the homogeneity seemed something desirable, and not at all an impediment. Another motive was the simple realization that a block grid, although difficult to implement in a computer program, once established, would be much easier to adjust and manipulate than line geometries. This followed from the experiences during and following the first artefact case. Here, addition and subtraction to the model becomes a matter of setting and clearing unique tiles. The trade-off in comparison to line geometries is that the grid resolution will also be the absolute limit to the model accuracy. (Figure 42.)

[11] According to the Oxford English dictionary, the word *pixel* originates from *picture element*. Following this a voxel would be a volumetric element. Picture cell and volumetric cell seem logical alternatives.

Figure 42

[12] LeoCAD and BlockCAD, both were available as free programs at leocad.org and blockcad.net respectively in 2011.

Nowadays tile-based modelling on computers is much more common than in the past, and during the past decade this cubic aesthetic has been increasing in advertising, computer games and "pixel art". When making this artefact, I was not seeking to connect to this graphic aesthetic, but to get at the questions of directly and rapidly modelling interior space. Personal experience suggested that very few modelling programs allowed quick tile-based modelling in a way that would make it comparable to sketching. Of the more widely available software, Google SketchUp does not allow tile-based modelling although it is otherwise fast for producing masses of objects. In a more obscure direction, looking at two Lego modelling software packages[12] revealed them to be inadequate for my purposes. The packages were in some respects slower than working on real blocks. This seemed to defeat the point of using such packages, as then almost any modelling software could be used for slowly building these forms. What I was looking for is a way to work in a manner that exploits the tiles for speed and expression.

As the project proceeded, it became clearer that certain ways of drawing, such as perspective drawing, relied on cubes or rectangular geometry. Converting an understanding about design drawing into computer software is a common premise in design software development, yet it is more often achieved through line geometries. The grandfather of all modelling software, Ivan Sutherland's Sketchpad, was already based on similar motives, and the prototype was presented as a graphical dialogue between man and a machine. Sketchpad relied on constraints that are intrinsic to using lines, such as enabling easy connections to start and end points. Further constraints and assists helped the draftsman connect lines

hierarchically. (Sutherland, 1963.) These are powerful ideas, and most modelling programs are even today underpinned by similar assumptions about line geometries and constraints. Making moves in feedback with rapid computer graphics is what makes direct manipulation (Shneiderman, 1983) possible. Even if adjusting lines on-screen is relatively direct compared to numeric data entry, it is still quite far from the kind of directness allowed by pen-and-paper sketching.

Using the cubic structure as a basis for software is here presented as a way to relate the program to an alternative drawing technique. Again, this motive was not immediately clear when starting to devise the software. I was even concerned as to whether or not it was worth pursuing something as familiar as the tile grid. Although less common in modelling software, tiles and bricks are of course extremely conventional in real-life building. Although novelty of form is not the issue here, the question remained as to whether the rigid grid in overall would prescribe ill or undesired effects. Yet grids are more than just assistive or prescriptive devices. Mary Higgins has examined the way grids have played a part throughout history, in city plans, construction, textile industry but also in ledger books, musical notation and art more generally (Higgins, 2009). Grids can be considered so ubiquitous and generally applicable as to go beyond mere style. They can be considered almost integral to paper-and-pen drawing, even if the drawing itself would not evidence grid geometries explicitly.

4.2 Building the software

The important stages in designing the software are more straightforward than in the previous artefact and more room is given to interpreting the outcomes from the tool. I also examine outcomes provided by other designers as part of the artefact exploration process. Asking others to use software under development can yield material on the different approaches and ideas arising from the tool, and allow inspection of the tool more broadly as a generative basis for design ideas.

Figure 43
Figure 44
Figure 45

This software described here uses a three-dimensional tile structure as basis for sketching forms. The forms are created incrementally by moving a cursor in three dimensions. The cursor only moves along the main dimensional axes. The software offers a perspective view into an environment made out of little tiles. A horizontal surface of 255 x 255 tiles is given as a starting point. The full extent of the modelling space is 255 x 255 x 128 tiles. The view is navigated using a combination of mouse and keyboard commands (Figure 44). Existing tiles can be selected and further grown in six directions (Figure 45). Selected tiles can be removed, or coloured using a fixed palette of sixteen colours.

The software was written during years 2008–2010, using C programming language and the OpenGL graphics library. The programming work was built upon the first artefact exhibition piece, which already supplied the foundation for view navigation. As the software returned to prominence in the research, a more decided design process was initiated to develop it further. It was dedicated that the software would only be designed to satisfy the flexible and rapid exploration of the selected grid. The basic way of manipulating the shapes persisted as the central element in the software.

First stage experiences with the software

In the two previous cases, other people have tried out some version of the artefacts. These situations have provided views to alternative routes and also helped in resolving the significance of the artefact in respect to my own aims. With the third artefact, I have pursued this route more extensively. I have collected outcomes from the tool use to provide a richer interpretation of the artefact. For the purpose of collecting these outcomes, the artefact was developed in two stages. These stages do not differ radically. In the second stage the software has been revised with some changes to the view manipulation and adding tool functions such as colour change. The produced outcomes were collected in modelling sessions where others tried out the software. This material helped in assessing how the tool supports their generative ideas. In this way a wider selection of outcomes was harvested than would have been possible if I had been the sole author. My own exploration revolved around experimenting with randomly produced shapes and modifying the results manually and through pre-programmed operations. (Figure 46.) Later, I settled on examining what I considered the most central aspect of the tool, the manual production of shapes as an analogy to design drawing. The first stage results are shown in Table 1 and Table 2. The second stage outcomes are found in Table 3 and Table 4.

Figure 46

As the software could be modified, it was possible to create a situation where I could see whether introducing a subtle difference in the tool would produce different approaches. In both stages, I introduced two variants of the software to the designers. The outcomes were inspected for evidence of different generative moves in fulfilling a given task and the influence of the program in choosing the moves. The material is primarily collected in order to expand the understanding of this artefact and the mode of working it supports. Although I have here stressed the difference between the two variants, the resulting outcomes are not analysed as evidence of the differences determining the outcomes. The difference in the variants is one influence among many.

Table 1 & 2
(p. 164–165)

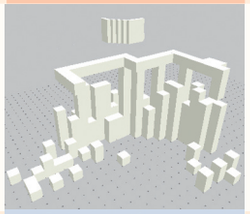
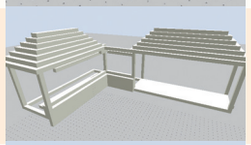
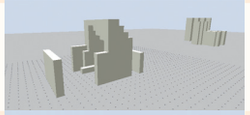
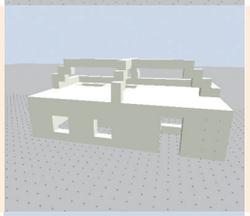
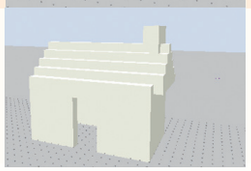
Tag	Thumbnail	Technique	Interpretation
I1		Add pieces and snake.	The idea of a story of a snow ball fight was realized by two shapes that fulfil the protective function in snow fight. Giving an appearance of protectiveness in snow fight results in a minimal structure that satisfies this requirement.
I2		Snake outlines. Taper roof.	The fortress theme influenced the choice of subject matter, a recreation of oriental fort typology. (Unfinished)
I3		Snake and grow.	Much as in I1, the forms offer protectionin a snow fight.
I4		Draw overall frame and fill in walls.	Moving around the model, opportunities for filling in and leaving openings were treated differently. "Igloo" feature on roof satisfies the outcome as a snow fort. Accidental shapes were accepted as interior with slight modifications.
I5		Fill in four walls, one wall at a time.	A recognizable "house" shape was chosen as starting point. The tool was used to build up the model one wall at a time.

Table 1

Outcomes from the snow fort task, created with the single cursor incremental version.

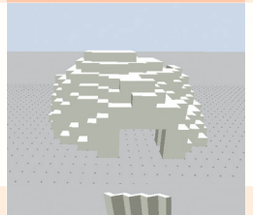
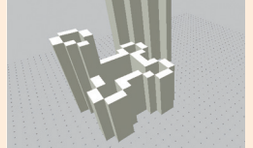
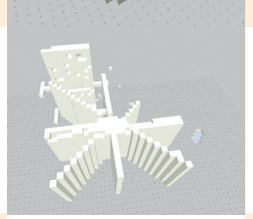
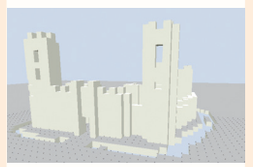
Tag	Thumbnail	Tool strategy	Interpretation
PS 3		Draw plan, extrude, work silhouette.	Recreation of an existing type (Igloo) is attempted despite difficulties. As a 3d pixel tool the software could be used to recreate organic form, an igloo.
PS 4		Draw footprint, extrude footprint.	The extrusion tool was used to quickly satisfy the task with a fortress plan shape. One person would fit to use the fort for defence.
PS 7		Draw footprint, extrude footprints.	The student displaced the snow fortress idea to a metaphor, making a snowflake shape plan through extrusion. Unfinished, ambiguous scale.
PS 8		Draw footprint, extrude footprints, detail by carving around the fort.	The appearance of a large fortress is the starting point. The initially drawn lines are allowed to guide the overall layout of the fort. The extrusion was used extensively to create parts of this fortress, one tower at time. Details such as arrow slits were carved in, while viewing around the fortress.

Table 2

Outcomes from the snow fort task, created with the paint selection version.

Overall, 24 people participated in the collection and produced outcomes from tasks, some producing more than one model. The collection was arranged with design students enrolled in a master degree program in furniture and interior design and industrial design. The male (11) and female (14) participants were all under 30 or near 30. Also at this stage, design researchers were included. In this way the people were not far in design experience to the author. The situations were intended to be like a designer showing a design tool to another designer, instead of a strictly controlled data collection session or a user study. Generally the designers had some familiarity with modelling software and some had experience of the use of computer aided design packages in their workplace. Both collections were made during 2010. The first is based on an initial version of the software, and the second was produced after adjusting the program.

VERSION I: SINGLE CURSOR INCREMENTAL (I)

The incremental variant (Tagged with "I" in the tables below) uses a single moving cursor for all shape creation. This means only one tile can be moved at all times. (Figure 45, left. The dark tile on the right is the cursor.) The cursor is moved by using six movement keys, almost like a cursor in a word processor. As the cursor moves it leaves a solid trace. A long, tall wall has to be built by moving the cursor through all the required positions. Removing existing tiles is also a similar process. Existing tiles can also be removed by selecting tiles one by one and pressing the delete key after each selection.

Figure 45, Left

VERSION PS: PAINTED SELECTION (PS)

In this variant, it is possible to select a large amount of tiles by painting them with the mouse pointer. The movement keys are then used to move not only one tile but all the currently selected tiles into the desired direction.

Figure 45, Right

(Figure 45, right. The selected tiles are darker.) A wall can be created by selecting a row of tiles and then raising the tiles upwards to the desired height. This can also be done sideways or towards the depth axis. It is still possible to use only a single tile as a cursor, and also remove arbitrary shapes of tiles with the delete key.

Working with the designers

For the first collection the designers were given a task of building a snow fortress, within 20–30 minutes maximum of time to produce it. This choice of task was motivated by the colour limitation in this earlier version of the software, which only allowed shaded white blocks. The on-screen activity was recorded with a video camera. The designers were assisted, when necessary, in using the program functions. The models and logs were examined for evidence of different choices of approach. The video and log material was reviewed and different techniques were noted. The approach to building the outcome was examined as a potential strategic choice, the person's interpretation of what works with this tool.

The paint selection (PS) version allowed the people to make the overall shape out of extrusion, and they often exploited this feature. The designers defined a footprint and then extended it upwards to the desired height. Under pressure of time, it was predictable that this function of the software would be exploited. It also resembles the way shapes would be created in common modelling software packages. As the incremental version (I) does not allow this kind of extrusion, the designers were forced to produce the parts unit by unit, either one wall at a time or by defining the

overall frame of the building and filling it in.

Using the incremental version, the designers had to make the building out of a "snake" type continuous form. Even then, this would result in different approaches. Some would first build a two- or three-dimensional outer frame of the whole object, which was then filled afterwards (I2, I4, see Figure 48). An alternative was to build the overall frame with one wall at a time (I5, Figure 49). These crudely correspond to the way a pen-and-paper sketcher can rapidly produce shapes in different ways. Overall, the task setting, although quite whimsical, proved to be more productive than the differences in the program versions. As the snow castle task is given in spoken language, it will be almost necessarily interpreted in different ways. The outcomes represent a variety of interpretations for the task, given the time limit and the constrained nature of the software.

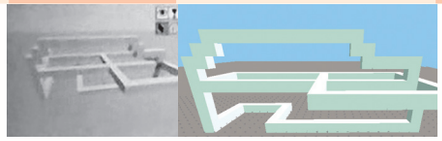
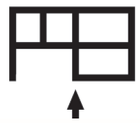
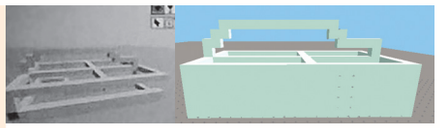
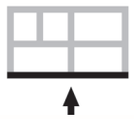
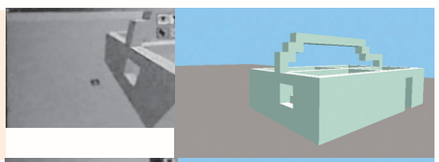
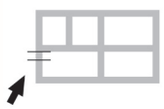
Figure 48
Figure 49
Figure 50

For example, the snow fort was interpreted as a protective screen (I1, I3, PS1, see Figure 51) or as an iconic fortress (PS8, PS4, see Figure 52). The former interpretation seems to arise from considering the physical presence of people in some action, or even a story about a fight between two parties. These models might actually be built for an impromptu snow fight. The latter models, although satisfying the defensive idea, presented the castle as something that would be more complex to build. One outcome model was a metaphoric snow flake form, representing the largest conceptual shift present in the collected outcomes. The snow flake appears as a new "primary generator" that bypasses the brief and the nature of the tool (PS7, Figure 53). The maker considered the model unfinished, and even the scale remained ambiguous.

Figure 51
Figure 52
Figure 53

I will present one of the making processes in more detail to give a picture of what it is like to design with this software. This model (I4) was part of the first collection. Here the designer has given the building an outline, and then added doorways and windows in the process. (Figure 54 and Figure 55.) The software environment is rich enough for a variety of generative choices, which are often based on identifying opportunities in the shapes produced earlier. Setting up the first three-dimensional frame for the outlines of the building also divides up the house model in a way that is taken advantage of in a later stage. The enforced first person view is a major influential element in the process. In this earlier version of the software, the view position cannot be rotated around a chosen point. Instead the viewing position has to be turned around and moved left, right, forwards and backwards. This makes the view much more limited and narrow than is usually available in modelling programs. In the absence of a plan overview, both literally and perhaps cognitively, the designers tended to solve details as the unfinished elements come into view. In the example, the designers worked the model from the exterior one wall at a time, only treating the interior when it occurs to them to move the view to the inside. There, the opportunity is taken to use the already existing, "accidental" shapes as basis for completing the interior space.

Figure 54 & 55
(p. 170–171)

Time	Video source	View clarification	Plan view	Explanation
5 min				A three dimensional frame is made by moving the line in all directions. The roof is adorned with an "igloo" shape.
10 min				The four outer walls are filled in one at a time.
11 min				A side wall is filled in.
11 min 30 sec				After filling in this wall, a window opening is added afterwards.
15 min				Moving to the other side, another wall enters the view. The existing shape and its division is a result of the first frame.
15 min 30 sec				Half of the wall is filled in and the rest of the opening is allowed to remain as a window.
16 min 50 sec				After the walls are worked out the roof is filled in. Some of the openings are retained as skylights. The division is a result of the initial frame.
19 min 15 sec				The rest of the roof is filled in.

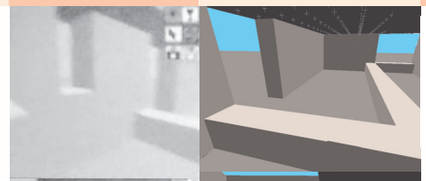
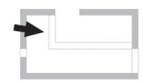
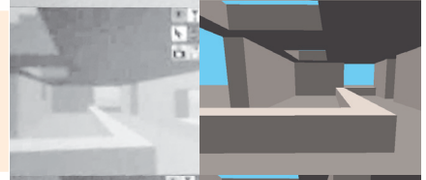
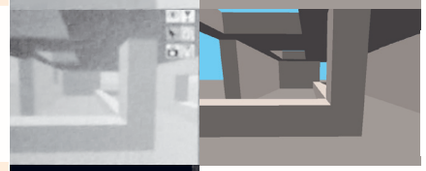
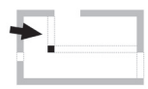
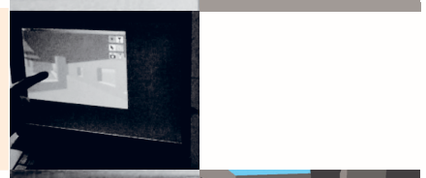
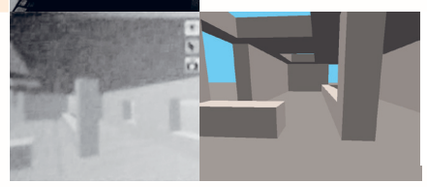
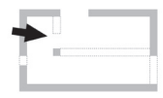
Time	Video source	View clarification	Plan view	Explanation
22 min				After working the roof, the inside is viewed for the first time. (It is only viewed from this one point.)
22 min 05 sec				The interior is an unplanned result of the initial frame and the work on the outer walls and roof.
22 min 20 sec				A pillar is added to the centre of the building to the corner in the existing structure.
22 min 34 sec				It is pointed out there is no passage between the two parts blocked by the original frame structure.
23 min				The passageway is made to the closest point. This is the end result.

Figure 54 (p. 170)

Outcome of the case I4. The video mater ial is highlighted for significant events. The building shape is worked from the outside, and choices are often based on the initial fr ame. Combination of adding and subtr acting approaches are used at different times. This outcome was built by two spatial design students.

Figure 55 (p. 171)

Outcome of the case I4 continued. The viewpoint is moved inside the building for the first time. The inter ior layout is revealed as a result of all the previous moves. Fur ther modifications are done from this view.

Experiences with the revised version

After the first collections with the two variants, adjustments were made to the program. Some aspects in the software appeared as obstacles for achieving the aim of the tests. One such obstacle was the cumbersome view motion. Colours were added to the new version, and the view manipulation was changed. The new view method followed conventions in common modelling software, allowing the person to rotate the view around a chosen point. Earlier, the view could only be changed through moving towards specific directions. This earlier idea was meant to support shaping the space from an interior viewpoint. In my personal experimentation this had proved to be an adequate solution, but for the designers doing the task, the viewpoint manipulation mostly caused inconvenience. As the choice of viewing method did not provoke any interesting approaches there did not seem to be a good reason from preventing others from using a more familiar way.

The new open ended task meant the participants could produce the kind of space or object they wanted. The only advice was that they should not copy an existing shape or building, and that they had to complete the task in one session, preferably in less than 30 minutes. The second stage resulted in more outcomes, but these displayed fewer new approaches compared to the earlier stage. In some ways, the open ended task produced less rich results than the snow fortress task. Only the more sophisticated second stage outcomes are presented in Table 3 and Table 4. This time the outcomes were collected remotely, as the program was enhanced with a built-in logging tool for collecting the processes. The participants were generally MA design students, although some non-designers and young professional designers also took part.

Table 3

Outcomes from the open ended task, created using the incremental toolset.

Table 4

Outcomes from the open ended task, created with paint selection toolset.

Table 3 & 4 (p. 173)

Table 3

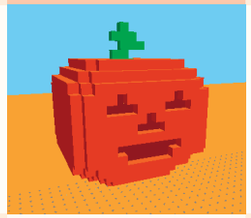
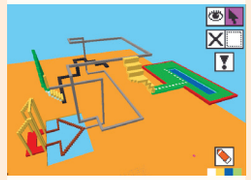
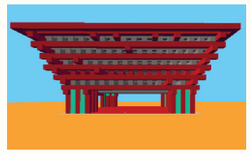
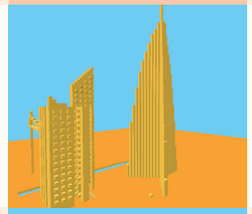
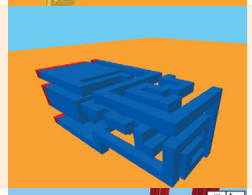
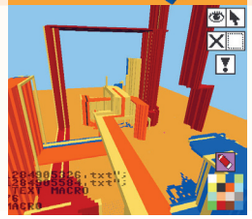
Tag	Thumbnail	Technique	Strategy interpretation
I21		Sculpting.	Choice of object first, a meticulous execution through sculpting the object outline. The holes for eyes and mouth are carved in the end. (Made by a non-designer)
I22		Snake in 3d.	Motion of cursor suggested motion as basis of the model. An association between a maze seen in a TV contest and the model inspired its development. The result combines schematic, abstract elements and representational, such as an arrow, a tree and a swimming pool.
I23		Snake and grow.	Existing building was copied through detailed modelling. The choice of model was suggested by the tile properties.
I24		Snake and grow.	The tile properties suggested a connection to a type of oriental ornamentation, which was executed through detailed modelling work.

Table 4

Tag	Thumbnail	Tool strategy	Interpretation
PS 20		Extrude footprint then extrude facades.	Building footprints were drawn and then extruded to height. Balconies were also extruded horizontally. The software was used like a conventional modeller.
PS 21		Grow and detail work.	Single cursor was used to make snake form on the paint selection version of the software. Tile properties were the origin of the aesthetic style of the object.
PS 22		Random experimentation.	The selections are allowed to grow accidentally. The awareness of what is and what is not currently selected does not appear to be clear. This leads to creation of inadvertent abstract shapes.

The students did the task themselves first, then were encouraged to send the software to a friend. In this way more logs could be gathered. The weakness in this setup was that it also provided material that was incomprehensible to interpret and had to be dismissed. This could have been overcome by inviting the people to discuss the work done, but this was not done systematically for all the works, especially if the result did not appear interesting or the person lived in another country. It was apparent that some designers would try to complete the task quickly when they discovered an effective means to complete it (PS4, Figure 56).

Figure 56

As the second task set was more open than the first, the designers had to set their own brief. Some designers seemed to take the tool properties as a starting point for their own ideas, whereas others would work on an idea that was already quite fixed when they began. In the latter case, it was more a matter of modelling something that already existed as a clear idea. This can still be interesting from the generative angle, as the object to be modelled was chosen on the basis of the person's initial perception of what the program could do. The idea may be followed through even if it takes time. For example, an igloo and a Halloween pumpkin (Figure 57) appear to have been results of such a choice.

Figure 57

Despite the request to avoid copying existing forms, one chose to model an approximation of the China Pavilion for Expo 2010, which also has a block-like visual identity (Figure 59). As a choice, this is not too different from the pumpkin and igloo examples. The software has suggested a suitable objective. An Oriental influence crept into other works too. In two cases (I2, I23) it also coincided with the designers' cultural background, whereas one Finnish person also made oriental decorations apparently suggested by the tile material (I24, Figure 58).

Figure 58
Figure 59

Figure 60

Perhaps the richest outcome in the second collection was a model based on an idea of a television show where contestants have to negotiate a three dimensional maze (Figure 60). Here parts and three-dimensional paths float in space, ignoring the laws of physics. It becomes ambiguous as to which part might be meant to be understood literally and which are "suggestive" lines, such as might be used in a sketch to depict routes. In recollecting the progress, the designer said the idea was suggested by the way the cursor snakes around the space three-dimensionally. This motion suggested a theme strongly related to movement. Symbolic objects and abstract paths are positioned with each other.

The outcomes represent directions that have emerged from encounters with the software. In some cases, the tool has provided more significant starting points for the whole aesthetic of the outcome, whereas in other situations the designers asserted ideas of what to produce. The short duration of the situations probably prevented most from exploring the potential of the setting, and some fulfilled the task in a very perfunctory way, perhaps suggesting a lack of interest. The way the task was set up meant the participants usually had to finish what they started. This has also to do with the properties of the software, as it does not provide ways for editing large portions after they have been built. The results emerge mostly through additions that suggest further actions. In rare cases, the designers took opportunity to invent a properly new guiding idea that, in dialogue with the presented software helped them achieve the outcome. (I22 and PS7.)

This look at concise situations of using the tool has provided diverse material on what can be achieved with it. The processes and outcomes also show that a variety of approaches can be undertaken, as the environment is rich enough to evidence design generative choices and moves.

The tool does not determine the outcomes, but plays a part in their formation. The software articulates one approach toward making spaces, and the collected material shows something of the scope of this approach. Usually, tools that are already established and shared between practitioners also inspire dialogue and debate of their meaning and worth. As the tools here are self-built discussing, this role of the tools may be lacking. With this task material, I have hoped to some extent counter this potential problem. The tool becomes a centrepiece for dialogue, providing additional material for reflection in this study. I cannot vouch for any sustained reflection on part of the other designers, but it can be seen that the outcomes emerged from a work with the tool in different ways.

4.3 Design drawing

The literature in this artefact case relates to design drawing and specifically perspective drawing. The idea and motive for building the artefact arose not only from the prior artefacts but from experiences with drawing spaces. The experiences from building and using the tool are also fed back into pen-and-paper drawing. The view here is that making design generative moves through drawing is already a design skill, better discussed as design drawing. In this chapter the tool-building has been directed towards the idea of building one's existing skill and knowledge through building the artefact. Perspective method books, as precedents, offer more specific examples of how this has been attempted.

One pragmatic reason for design drawing is that an object, which may not be convenient to craft directly, can be provisionally laid out in a drawing. (Lawson, 2004, 32.) Another reason is that the drawings afford, as John Christopher Jones put it, a "greater perceptual span" (Jones, 1981, 22). Ching, an author of popular books on design and design drawing, described sketches as "speculative drawings", putting weight on their private nature (Ching, 1997). In addition, Suwa and Twersky (1996) have pointed out that professionals use the sketch to consider non-visual functional relations not explicitly evident in the sketch. Sketches can depict appearances, but also immaterial things like propagation of light and sound. Much of the discussion on design drawing has been summarized in Donald Schön's (1991) metaphor of drawing as talk-back. When the designer uses drawings to advance a definite design object, clarifying each aspect in turn, there is a dialogical nature to the process. Importantly, often it is the unintended in the situation that begins to "talk" to the designer. (Schön, 1991, 76–79.) Although the speech metaphor is illuminating, some wariness should be exercised. The metaphor seems valid in as much as the process involves stopping to think, stimulated by the new angles emerging from the sketch. But the metaphor may also lead to see drawings as utterances, or merely an alternative way by which to communicate a thing that could have been in principle spoken. The process of drawing is continuous in a different way than speech, and images show whole environments and relations in a way that would be difficult to describe in words.

Bryan Lawson (2004) has offered a broad taxonomy of design drawing that relies on intent rather than appearance. Design drawings would include presentation, instruction, consultation, experiential, diagram, fabulous and propositional drawings. In principle, any of these drawings could be made as a perspective or a plan. Conventionally, presentation

drawings tend to be natural images and architectural space often emerges from plan and section sketches. Lawson's understanding of design drawing is a "what-if" tool that integrates aspects of the thing to be eventually designed. (Lawson, 2004, 54.) What Lawson terms fabulous drawings are speculative and visionary, for presenting design propositions uncritically. Diagrams, such as bubble plan diagrams or route drawings may be used to clarify the requirements and the problem setting before proposing an actual outcome form. An early design sketch can have any of these characteristics. Of Lawson's taxonomy, the propositional drawings are the most relevant here, although fabulous and diagram drawings can clearly be generative drawings. The propositional drawing is the central design drawing, "where moves are made" (Ibid., 2004, 45) and are analogous to Schön's conversation drawings. Lawson also stresses there is no reason to assume a hierarchy in a propositional drawing, such as a direction from the more vague to the more definite.

The artefact case is examined with respect to one specific mode of drawing that is connected with the artefact development. Perspective is seen as one important generative base for making design drawings, an angle that is exemplified in the perspective method manuals. It is also a continuation on the themes discussed in relation to the first artefact, that of visibility and perception. As the perspective methods in the end tend to guarantee similar imagery, the attention here is put on the difference in presentation and argumentation; in the way the pictures are arrived at. This is probably the only way to see different perspectives as relative and personal, not in terms of their appearance, but in the way the method is employed to produce an outcome.

Critical views to design as drawing

One of questions early design theorists attempted to settle has been whether to draw or not to draw. The early thrust towards design research wanted to abandon drawing as inappropriate for addressing the kind of problems design was now needed to grapple with (Gedenryd, 1998, 3–4). The role of drawings in design is by no means definite, and not all design requires drawing or benefits from it. One of the original proponents of design methods, John Christopher Jones, derided what he termed "design-by-drawing" approach as something that takes the intellectual decision-making from the manufacture and puts them on the drawing board of the designer. To Jones, this kind of design can no longer be effectively evaluated in its real context, but instead becomes a process of learning to do good drawings in apprenticeship. (Jones, 1980, 20–24). Echoing Jones and Alexander, C.T. Mitchell, in *From form to experience* (1993), sees design-by-drawing problematic in that it would make design rely on the intuitive decisions of an individual designer. In craft culture there tended not to be separate model and an outcome, and objects evolved over long periods of time. Introducing drawing as a separate phase brought detachment between envisioning and making. (Mitchell C.T., 1993, 42–44). Jones, while defining designing as an activity that "initiates change in man-made things" (Jones, 1980, 4), saw the move away from drawing as a step towards maturity in design theory. The designer would not be defined as the one who draws. Design, both as a verb and a noun, was not be equated with drawing. Drawing was seen as a tool that might or might not have a place somewhere in a design process. In part, the could be seen as a backlash against what was seen as superficial styling of the kind seen in the illustration-oriented industrial design at the time. But it was also an attack on the designer's and architect's supposed ability to envision future situations through the drawings alone. Alternatives to traditional drawing were

sought, including diagrams, graphs and matrices that would objectively describe and map design problems and their dependencies. For Christopher Alexander, this labour on problem and solution elaboration was the real essence of design (Alexander, 1964, 3–4). In principle it is not necessary in design to draw at all. Computer programs, which were beginning to be available in universities at that time, seemed to promise just this route, showing a way out of what was seen as superficial design. This rational, prescriptive design method approach in its strictest form proved to be unsuccessful. (Gedenryd, 1998, 58; see also Cross as paraphrased in Luck, 2006). Much of the above relies on an assumption that the principal reason for drawing is to visualize the imagined object yet to be. But just as the designer may find design opportunities in found objects or random shapes in the environment, he or she may discover design opportunity in a self-created sketch produced outside a specific task. More balanced views on design drawing started to appear as real world design practices were examined. Schön's view of drawing as one possible medium in which to exercise reflection-in-action is an example of this (Schön, 1983, 157).

There is a loose analogy between the debate on design drawing and the application of visually oriented simulation and visualization in natural science. Peter Galison (2002) examines what he sees as a dual attitude towards images in science. According to him, leading scientists have in various times attempted to dismiss the image in favour of abstract thinking in science education. Even then, in practice, physics students found refuge in image-based tools and notations. Galison polarizes:

"We *must* have scientific images because only images can teach us. Only pictures can develop within us the intuition needed to proceed further towards abstraction. [...] We *cannot* have images because images deceive. Pictures create artefactual expectations, they incline us to reason on false premises." (Galison, 2002).

In fields like molecular science, theory can become more alive in simulation, as the processes in themselves can never be seen. As Sherry Turkle says, paradoxically the unreal makes the processes more real. Yet simulation and computer programs have the tendency towards black boxing, making opaque the underlying principles of the simulation itself (Turkle, 2007, 26–27). The debate of images in natural sciences does not have an exact counterpart in design, as many design drawings do not act as simulations. Yet the "falling into each other" of the numerical and the image (Galison, 2002) could find its counterpart in how design alternatively favours generative imagination and mapping real-world properties. The debate between intuitive drawing and addressing real world problem-solving is perhaps a similar tension that will never be resolved in full favour of either. Yet, a more conscious understanding on drawing and modelling could prevent them from becoming black boxes to the designer. If one employs drawings and computer visualizations in design, it would be appropriate to know what they bring in to the mix.

Perspective drawing and design

The very word perspective brings with it enormous baggage, considering the amount of scholarly study and philosophy devoted to the subject. Here, instead of tackling perspective in its full depth, it is more important to trace a tradition in perspective that is closest to the design interests at hand. This means that the focus is on the making. The idea of perspec-

tive method is examined as something built or designed. For this effect, I examine books that present perspective drawing methods intended for designers, made by designers. Through this choice I put primacy to the design fields' view on the subject, and consider this tradition of knowledge sharing as a potential mode for practice-led research. This choice of focus excludes analysis of perspective in art, perspective for illustrations and advertising, and principles in descriptive geometry. Three examples of perspective method books are brought into the discussion as they explicitly present the methods for an intended context within design, or even attempt to define design.

In the first artefact chapter, aspects of spatial perception were discussed as a point of entry for reflecting on one's personal theory of space. Here I want to clarify my standpoint on perceptual, perspective images as a way to generate spatial design material. Ideas about the validity or falsity of perspective images abound. Design perspective manuals might even be seen as doubly subjective: both the methods and the outcome images would be detached from any solid facts. Rescuing the method manuals from such relativity gives a more permanent handle for addressing their design relevancy. The question is whether any perspective is intuitive to understand or involves a way of looking that needs to be learned much like a language. Erwin Panofsky was first to strongly argue that different perspective constructions in different eras convey different modes of thought and that there is no one valid perspective (Panofsky, 1991). This paved way for a relativistic interpretation of perspective. The philosopher Nelson Goodman, in *Languages of art*, suggested as much with reference to the anthropologist Melville Herskovits. According to Goodman, Herskovits' tells that in numerous accounts of anthropologists showing photographs to people naïve to such images, the pictures have not been immediately understandable. Goodman inferred from this that perspective is arbitrary and has to be learned like a language. (Goodman, 1976, 14–15.)

For the purposes of the present case, the issue is in my view sufficiently resolved in Gibson's ecological optics, which offers a sound argument for a natural image. The pictures capture partially the same perceptual invariants as in the real environment. It might be attractive to think outlines in drawings as an indication of a developed convention. Following Gibson, the edge outlines are instead a powerful approximation of edge invariance experienced in perception. Gibson countered Panofsky and Goodman specifically, saying that the perceptual invariants cannot be put into words or symbols, and hence do not constitute an arbitrary language (Gibson, 1986, 285). Furthermore, the way Goodman makes use of his anthropological backing is not very convincing. Paul Messaris discusses Herskovits' one specific anecdote, that of an African woman not being able to identify her child from a photograph until the features were pointed out to her. Although the original observation is valid and interesting in itself, Messaris says, it is not necessarily the arbitrariness of a photographic image that becomes evidenced, as the confusion may arise from the situation being the person's first encounter with paper material. Crucially, the learning how to "read" the photograph happened so rapidly as to dismiss the idea of such an image as a language. (Messaris, 1994, 60–62.) This is not to say there is no cultural background involved in perceiving an image, but it does not weigh too heavily against this practical basis of natural images. Goodman's obvious note that images do not convey the full experience of being there, as a photograph of a mountain clearly demonstrates, is still sound (Goodman, 1976, 14–15).

There is not any overtly convincing case for full arbitrar-

iness of natural images. Herein is ground for debating the suitability of these images for design, and the images as concrete proposals of what could be. Rust and Whiteley (1998) discuss realistic pen-and-paper sketches in the context of designing prosthetic limbs, accompanied with anatomically accurate drawings. Through drawing, Graham Whiteley explored mechanical aspects in design problems as wholes, the alternatives and analogues propelling forward the development of a prosthetic arm. The rapid drawing was used to bypass some of the more conventional assumptions about how such a technical project would proceed. It especially seemed that in the mechanical context, drawing could help overcome or postpone the need to identify whole-part relations formally. (Rust and Whiteley, 1998.) This is one application of realistic design drawing, as a good command of drawing allows one to quickly articulate various alternatives as wholes. Compared to Whiteley's project, drawing spaces here is in some aspects simpler, lacking the mechanical moving parts. Although a mastery of a drawing technique could be integrative towards technical systems such as ventilation and pipes, drawing is examined more as a way to explore and propose about experienced, interior space.

Perspective methods as personal theory

In the above I have argue that certain type of drawing is not arbitrary, but that they show environment solidly. Now attention is turned to the various routes toward creating these images. Perspective manuals, many written prior to the computer modelling era, are examined as a candidate for distributing design knowledge. As a rigid projective method, the rules of perspective drawing promise an outcome despite the overall drawing skills of the draftsman. In this sense the methods can provide knowledge in the form of clear procedures. The other knowledge, or knowing, is in learning to draw such images in free hand for the purposes of design generation. This knowing does not become immediately grasped upon viewing such a book, or from following a clear recipe. This does not prevent the method books from transmitting ideas that are relevant to building up the skill.

A central concern in practice-led research is the interpretation and communication of the things done. In this sense, the perspective manual offers an insight into one way to distribute design knowledge, which has partly resided in the writers' drawing and design skill. Although the underlying principles in perspective are the same, the different authors colour their presentations with their own views and beliefs. Each manual is presented from the perceived needs of one context, such as industrial designed objects or interior space. I have chosen to compare the present artefact case in relation to work on perspective methods, as in my interpretation each method demonstrates an approach to questions about space. In the following, I will examine three different perspective manuals[13]. Influential perspective manuals such as Jay Doblin's *Perspective: A new system for designers* (1956) and William Kirby Lockard's *Design drawing* (1982) stress that the rigid perspective drawing method should be seen as a stepping stone in learning to draw views directly in free hand sketching. *John Pile's Perspective for interior designers* (1989) provides simplified techniques for drawing inside views.

Jay Doblin's book, *Perspective: A new system for designers* from 1956 focuses on ways designer might use to learn to draw objects rapidly. He first suggests that previous drawing meth-

[13] I have drawn the accompanying illustrations in this section using the methods discussed. These illustrations have been made in 2012, after the other design and drawing work in this thesis.

ods were primarily aimed for architects, who zprefer plans as their central drawings. The architects would use perspectives mostly as final illustrations. Instead, industrial designers "must work out his ideas in the round" (Doblin, 1956, 7). Aimed towards American industrial designers at the time, the emphasis is on drawing such consumer desirables as automobiles, stereo turntable equipment and electric razors. Doblin's book really culminates on the idea that free hand drawing can be based on exploiting cube geometries. Only the mastery of this freehand skill is a real understanding of perspective. (Ibid., 1956, 56) When this becomes second nature, in principle almost everything can be drawn.

For Doblin, the validity of his method lies in its accuracy, and proof is offered that the drawing methods produce as accurate results as the previous mechanical constructions. Doblin's first choice is to limit the potential number of views to the three most useful ones, showing how to construe "absolutely accurate" (Ibid., 1956, 15) cubes from these angles without plan or elevation drawings. (Figure 61) Furthermore, the draftsman can control the drawing size and errors more easily than with previous constructions, simultaneously supporting development towards the freehand skill. The three proposed drawing angles are the diagonal 45 degree oblique view, 30–60 degree view and a parallel, frontal view. The 45 degree view is presented as simplest to construe, whereas the 30–60 degree view offers a more natural angle to the object. For each view type, there is a way to produce an accurately proportioned cube. When this first cube has been established, it can be divided or more cubes can be added to it. The procedure for drawing the first cube can become a mnemonic device which ensures the correct proportions. Doblin mostly concentrates on objects, and the interior view constructions are not as comprehensively discussed. Doblin claims that angled views are poorly suited

Figure 61
Figure 62

for interiors, for which purpose he offers frontal views construed with one-point perspective.

William Kirby Lockard's *Design Drawing* (1982) is a thorough exposition of perspective drawing. The book is principally about perspective, but as the title suggests, it is not presented as a special drawing but as *the* design drawing. Lockard takes a strong position that architecture ought to be about the experienced human environment, and to this end direct perceptual images should be the principal aim in developing design drawing skill. The book is not wholly a practical manual, as it is made in dialogue with the emerging general design methods. For example, concerning education, he suggests that learning drawing should always be connected to design tasks, and as an end in itself ceases to be a design drawing (Lockard, 1982, 7). The whole treatise cannot be opened up here, as the topics are very diverse, ranging from specific texturing techniques to an essay on human thought. My examination focuses mostly on how the central drawing method is conveyed.

Despite the generalizing title, the advice is geared towards drawing interior environments. Lockard has repurposed Doblin's method for environmental and architectural design, rejecting the plan drawing tradition. Lockard too saw plan projection methods as needlessly complicated, as it is possible to produce convincing enough drawings without the projection. As a rhetoric device, a complex image collected from an earlier perspective book is presented, in which a huge array of intersecting assistive and projective lines lead to a comparatively simple outcome. In contrast, Lockard describes what he calls a direct perspective method, a way of drawing the outcome image without too many preparatory drawings (Ibid., 1982, 106–107). This resembles Doblin's advice, and Lockard explicitly refers to Doblin as the father of the cubic drawing method, expanding his own ad-

vice on similar lines (Ibid., 1982, 106). The direct drawing method does not mean there are no auxiliary lines, but that they are drawn only at required moments. Lockard follows Doblin in showing how a single cube can be expanded to its principal axial directions, preserving proportions in perspective. This is done carefully to show how accuracy of measure and dimension can be retained in the free hand drawing. Lockard offers a variant of the method more suited to interior depictions. The required geometric planes and vanishing points are first established on paper (Figure 63). Instead of favouring a direct frontal view, Lockard provides a quick way for producing slightly tilted frontal views. It is initially construed by laying out the lines that make up the frontal plane, which can be made to coincide with a major interior wall or building façade. Although this setup would suggest an inconvenient vanishing point very far to the left, the point is not actually needed. The existing array of lines can be used for aligning the objects. Similar to Doblin's method, it is ensured that the size of the end drawing can be easily controlled. The proportions are ultimately subject to perceptual judgment, which Lockard encourages, rather than relying on assistive devices. The initial "depth guess" needs to be made for establishing the first squares or cubes to make the method work fully (Lockard, 1982, 108–110). Going further than Doblin, Lockard also provides his own concepts for structuring a spatial image. Many textural depth cues besides edge outlines are discussed, which become more relevant in an environmental image. He proceeds by separating what he terms spatial interest and textural interest. The former conveys, if put in Gibson's terms, affordance for body movement in space. The latter is tactility and the potentials of touch evident in surface qualities. Roof tiles, shingles and wooden patterns are part of the texture of the environment. (Ibid., 1982, 22–23.)

Figure 63

Lockard justifies the direct perspective images by referring to Gibson's perceptual theory, and the various depth cues are also linked to Gibson. Thus the justification for perspective is not really sought from a geometric proof, which sufficed for Doblin. This departure might be explained by Lockard's general stance. Design drawing is defended from the then emerging design method views, especially Jones' critique of design by drawing. Lockard attacks the method movement as advocating scientism and suffering from "physics envy" (Ibid., 1982, 12). In this light, the requirement of geometric proof resembles scientific or mathematical proof, as if the resulting picture needed to provide logical evidence of its construction in order to appear truthful and valid.

John Pile, an author of books on interior design, has also presented *Perspective for interior designers* (Pile, 1985). Instead of advocating direct drawing as strongly as Lockard, the outcomes are derived from an existing plan, supporting what is called a revolved plan method. A plan drawing is placed at the desired view angle, and lines are projected down to the intended view image. Pile clearly wants to preserve the plan as the central design representation. He claims that "designers work with plans, tend to think in terms of plans, and generally have accurate plans available of any space for which a perspective is to be drawn." (Ibid., 1985, 15) Yet care is taken not to introduce any unnecessary complications to the process. Two-point perspective is taught as the primary method, and one-point is presented as really a special case of two. Pile claims that learning one-point drawings exclusively results in an inability to produce the two-point variety. (Ibid., 1985, 15)

The method is claimed as serving interior design, as methods devised with objects in mind are not supposed to serve interior drawings so well (Ibid., 1985, 10). Pile devotes a chapter to free hand drawings, not only for working with

"conceptual sketches" but for impressing clients and other laymen with a concrete display of skill (Ibid., 1985, 98). It also seems the freehand approach is valued more for its "softening" and "artistic" (Ibid., 1985, 93) qualities than any real design value. The two-point perspective is geared towards producing oblique views. In contrast to the other authors, the angle for these views is quite strong, 30 degrees. This seems to result more from the convenience this angle affords for the projective method, rather than from an argument for the view's suitability. As the second vanishing point is needed, using a less tilted view would locate the point in an uncomfortable distance on the paper. Although the motive for teaching two-point perspective appears sound, it is not exactly clear why such perspectives would be desirable. Presumable it gives more freedom for depicting spaces more clearly or in advantageous angles.

Pile does not have an explicit justification for perspective like the earlier authors, but does offer techniques for deriving plans from an existing photograph or correctly rendered perspective images. The justification of perspective is implicit in this possibility for back-tracing and in the capability to produce outcomes comparable to photographs. Although by no means explicitly stated by Pile, I infer the idea is that the architecture and design community needs to archive design images in a way that presents the spaces unambiguously. Perspective images would not be an exception, and the possibility of tracing back the dimensions from a view validates them as unambiguous and thus acceptable as archived material. Yet in overall Pile's presentation suggests that drawing has been relegated to a position of an illustrative technique. Doblin is mentioned in the references as suggested reading, but there is no trace of the cubic method. Emphasising oblique views suggests a desire to present spaces favourably and in an interesting way. In the advent of computer

Figure 64
Figure 65

drawing, Pile's argument for manual drawing does is not too convincing, as it rests mostly on the argument that artistic touch and embellishment in the drawing can still be preferable in comparison to the mechanical output (Ibid., 1985, 156).

All the three manuals tend to favour renderings from an angle. Lockard claims the one-point views are static, coincidental views, "brides', bowlers' or firing squads' views of space". It is termed as uncharacteristic to the way space is experienced in motion, and in practice fails to present building exteriors in an interesting way. They are seen as more valid in depicting interior space, as the one-point frontal image can be clearer than an oblique view in this context. (Lockard, 96–97.) The angled view, instead presents the space in a kind of tension. The real value may be that the angled view brings more perceptual invariants into the picture than the one-point view.

Literature summary

The design perspective manuals are not limited to just offering methods for drawing objects, which was how earlier literature tended to address the topic. As made by designers, the perspective manuals present different methods, tricks of trade and rules of thumbs optimized to fit various situations and needs arising in different design practices. The manuals thus embody practitioner-originated knowledge, as part of a repertoire-building process much in the way that Schön suggested (Schön 1991, 315). Freehand drawing, emphasized by the authors, is a skill that is in many aspects difficult to verbalize. This does not prevent the authors from giving useful guidance as how to acquire such a skill. Although the skill

as an outcome cannot be easily discussed, the route towards it could be laid out. Not simply a how-to for explaining a procedure, the books contain opinion drawn from long experience, of how the designer could and should draw. This knowledge is transmitted in both images and text, and reference is made to precedents and prior authors.

In particular, Doblin and Lockard propose that perspective drawings ought to become a direct way of working with design ideas. It is at this point that perspective drawing becomes really a generative design tool and not just a device visualising what has been generated. Lockard is more radical in this respect than the other authors, who are more careful in not overstepping what they see as a boundary to their topic. For example, Pile seems to believe that design drawing is servicing as tool to the real design activities taking place in a professional context. Lockard also differs from the other examples in that he is very thorough in developing his argument for the method in the written portions of his book. For Doblin, it suffices to sketch an argument (albeit unclear) on the relation between perception and perspective, whilst Pile appears to consider the professional need for certain images as their central justification. As a result, his disposition towards the plan drawing produces a somewhat two-dimensional take toward space. Lockard's ambitious standpoint does raise some questions, though. He argues for the drawings as central design tools, but he stops somewhat short of saying what kind of design moves are played out during the drawing.

Following Gibson, the perspective image is seen both as a depth image and as traces on a surface. (Gibson, 1986, 282.) Although the image does not fool the perceiver to think of it as real space, the depth-interpretation nevertheless puts to question the idea that drawing on paper or a computer screen is necessarily "two dimensional"[14]. Again, this does not necessarily have much bearing on how the drawing is actually produced. When the rigid pen-and-paper methods are applied, it becomes necessary to set up an initial frame on the paper that aligns the further moves. Lines are projected along the surface, and as the depth image appears as an end result, the draftsman does not need to consider the depth image during the process. With freehand sketching, or what Lockard would have called direct design drawing, this outline framing becomes optional or can be accommodated to fit the situation. The viewing of the depth image is already done during the drawing.

Paul Klee famously took a line "for a walk", aimlessly wandering for its own sake (Klee 1961, 105). The lines on paper are not just aesthetic possibilities on a canvas but components of tools that can be guided towards various ends. To draw in perspective is to appreciate both the depth-image and the lines as traces. A view can be generated out of the traces. Klee's rare frontal perspectives (Ibid., 140–145) are a result of lines playing each other on paper surface instead of converting existing volumes into views. The vanishing point is not always even drawn but remains an idea that guides the lines. Klee's trace-making gives a complementary view to the three above examples in that it distils a generative aspect of drawing, removed from questions of design relevancy.

Looking at the three manuals, the differences in the methods arise partly from the different contexts they are intended for, but also from personal experience and aesthetic preference. Although any method no doubt presents possibilities for more general use, they are nevertheless presented alongside ideas about spaces and environments. To a degree, this is almost unavoidable in a book that attempts to describe perspective methods towards design ends. The books depict both desired results and a way to achieve them in drawing. My view is that even if these methods are geared towards

[14] Something like this becomes expressed in the opening leaf of the book *Perspective, projections & design*. "Architectural drawings must represent three-dimensional objects in two dimensions" (Carpo and Lemerle, 2008.)

certain kind of space or stem from personal preferences do not make them inferior as tools. On the contrary, the variety of available tools and the personal agendas behind them ought to be taken as richness, a source from which to develop one's own approach.

I have come to interpret the perspective drawing method as a rigging for exploring cubic volumes in a particular way, facilitating their generative exploration. Especially the freehand perspective method is a generative root for rapidly exploring the cubic shapes in dialogue with the drawing. Although the idea of perspective as cube-based can be found from the manuals, the interpretation in this form is not as forcibly presented in any one of them. In the practice-led process of this research, this interpretation was permitted by working with the artefact first and reading the manuals with these experiences in mind.

4.4 The reflective process: From drawing to artefact and back again

The longer process of this research is based on identifying personal tendencies and goals in a design drawing process and building the computer software in order to address these goals. Building the tool, using it, and examining outcomes of the tool stimulated reflection on the personal theory. The drawing and the software have informed the development of each other.

Drawing tendencies and goal identification

Figure 66

In this chapter, I have presented one way of exploring spatial form. Before discussing the outcomes of that process, I describe how this one direction came to be set as a goal, as outlined against a background of alternatives. A map of these alternatives is shown in Figure 66. These have been commonly present in my sketching, and I have considered them as tendencies rather than intentional directions or categories of drawings. Identifying the presence of these tendencies is a result of the first reflections on the tool building. The figure shows four alternative directions for drawing spaces. The top left corner depicts a room in perspective, but seeing it as a picture of space has much to do with the inclusion of conventional windows, doors and furniture. Likewise, the bottom left corner depicts a doll's house view to space, as an object viewed from outside. Both of these heighten the object of design as an organization of furniture inside a box. Peppering a drawing with an assortment of household items shows that it is meant to be understood as an interior of a house. On the right hand side of the diagram, space is given a dif-

ferent emphasis. The space is shown as a potential for body movement, regardless of any individual objects that would mark it as an interior of a building. This treatment can also be conveyed as an interior view or an external view. The top right direction has been the primary goal during the work on the artefact, and the other directions have been seen as less desirable.

As described above, I have pursued drawing space as a malleable cubic material seen from an interior view. Initially the other possibilities in the diagram were seen as altogether undesirable. But the identified tendencies are really a map of different possibilities, all of which can be employed during drawing. Furthermore, I do not want to suggest that the right side approaches are more fundamental, or that they would be more valid starting points than the approaches in the left. Throughout my work and in the literature it has been stressed that design can begin from one direction or another. Like Simon's "from inside out" and "outside in" these different tendencies are tokens for potential approaches. It might be argued that a good command of these all would be undergirded by mastering the abstract space drawing in the first place, but this is debatable. The decorated box can become a starting point for design tools just as the others.

The goal-setting described in this chapter was part of the reflective thinking supported by the initial interpretation of the artefact. The decided direction arises as part of a personal theory-building process. When beginning to articulate the desired direction, the reflection benefited from identifying these undesirable or opposable directions. The further work was then dedicated towards exploring the one chosen direction which was provisionally identified. Here the scope of what this one artefact can help say about these other directions ends. As such they have somewhat similar role to

the abandoned directions in the previous chapters. The work described in this chapter together with the literature, have been used to examine the scope of the chosen direction.

Skill development as repertoire building

When discussing freehand perspectives for design, I have focused on drawing as a skill and not merely a procedure for transferring existing plans to views. Of all the three artefacts this one has most clearly to do with clearly contained skilled activity. Whereas with the previous artefact it was suggested that part of design skill resides in the skilled employment of generative moves during the longer process of design, here the generative moves have been discussed as embedded in a drawing skill. This then becomes the third tool-building angle discussed within this thesis, a way to advance an already existing and developed skill. In the present case, the reflection on the skill development is achieved through building the artefact. Formalizations and explications provide material for developing a skill. Discussing the perspective method books also opened up the topic of distributing these skills through written and illustrated research outcomes. My starting point is that a broad skill like design drawing is unlikely to develop uniformly toward intuitive and acute knowing of spatial objects without at least some guidance or goals. Learning how to draw is not the issue here. My drawing skill, in most aspects, was already highly developed before the artefact case. It was the practice of picturing spaces in certain way that needed to be brought to the fore to reflection. This one way of producing forms and spaces is what the computer artefact

explicates. What needs to be explained is the significance of this explication for the purposes of reflection.

Dreyfus and Dreyfus have suggested a five-stage model for expertise, suggesting that learning of a skill proceeds through first understanding formal rules, eventually achieving competence and mastery where the rules are seldom invoked as such. (Dreyfus and Dreyfus, 1986, 16–51.) Chess playing is presented as a clear example of such a skill, where the decision making of more skilled individuals defy explanation and the play can be best described as intuitive. The master player is able to recognize situations, patterns and a variety of opportunities without being able to explain or evaluate the moves consciously. (Ibid., 1986, 32–33). The Dreyfus and Dreyfus skill model is questionable as skills are not necessarily learned via formalisms, for example, the way an infant learns to master his or her bodily capabilities certainly is not initiated by formal rules. However, this does not need to be an obstacle when considering the ways an adult learns to extend his or her abilities.

With an already existing skill, formalizations and explications have a part in developing them forward. Michael Polanyi (1966) has presented a case for what he calls interiorization, a subsuming of the explicit knowledge into a bodily skill. The knowledge of a theory is in the ability to use it, and its learning a matter of putting it to practice. (Polanyi, 1966, 17.) A skill, once established, may proceed through formalizing some aspects of it. The formalization of bodily skills may initially have a paralyzing effect on the skill, but as it is overcome the formal element becomes interiorized and is no longer thought about consciously. In fact, interiorizing the new formalizations is a requirement for fluently using the skill. (Polanyi, 1966, 17–20.) This is not far from Schön's reflection-in-action. Surprising situations provoke a felt need to begin conscious motion towards understanding some element in the practical work. For Schön, it is often a surprise result, in the case of skills a skill failure or unusually good performance that provokes reflection on the skill (Schön, 1991, 56).

Figure 67
Figure 68

This is one interpretation for the artefact. Building it was an act of articulating a narrow element in the drawing process, bringing it back to weigh on the drawing until the problems in the drawing process could be resolved. Although it did not result in any clear paralysis on my part, it nevertheless directed the drawing activity towards areas that were not immediately useful for the skill in general. Free hand perspective was shown to be a capable tool for generating design proposals and not just about making view from existing plans. Similarly, making computer software is not just an opportunity to remove drudgery from the rigid methodical perspective drawing, but a way to highlight aspects of how the freehand drawing works.

If a single surprise moment needs to be highlighted from the process, it is one that relates to drawing material for the program development. The program's development provided an opportunity to exercise the drawing for the purposes of programming the software itself. Some functions in the software needed to be visualised clearly before they could be implemented (Figure 68). In part, this already established the formalization that the program then supported. What then was the value to me of developing the software? It could even be argued that the software is redundant as the perspective manuals already demonstrate the value of cubic geometry. Making the software might then seem like a roundabout way of arriving at a personal discovery. Perhaps the literature could have been used to provide the formalisms needed for propelling the drawing skill forward. This minor "crisis" resembles the situation described in the previous artefact chapter, where the role envisioned for the physical tool

emerged as a conceptual move that could be realized with different means. Here too the artefact building precedes the insight. It is unlikely that this particular interpretation of the perspective methods would have been arrived at without the artefact. The software artefact distils one aspect of drawing that could be subsequently identified within the literature and in my own drawings. The artefact and the way of working it supports, supplies the model for what to look for. Yet stopping here would diminish the tool into an entry point to literature. The tool provides distinct ways of working and continues to act as a counterpoint to the drawing techniques. Instead of supplying ways for creating "primitive objects" in various sizes and proportions, the software gives a cube which can be rapidly extended to various directions. The cursor is taken for a walk. Putting the learning to work in drawing is not only a matter of diverting the drawing towards practices that produce comparable outcomes. The artefact building was an attempt to exemplify ideas about drawing not only in terms of outcomes but drawing as a way of making. The particular way of making, as a skill in the personal repertoire, is a personal theory built on the experiences. The artefact did collect together a viewpoint, showing a goal for developing the pen-and-paper drawing. Continuing on the theme, I have picked up a stream of thought also present in previous perspective methods and concentrated on that. The artefact and the actions it supplied became the objects for reflection, suggesting a dialogue between how to produce forms in the software and how these actions might have a counterpart in the drawings. A personal theory, or a belief system, is being built. The personal theory is about how to proceed with making spatial drawings and the skill it entails.

In addition to the cubic interpretation of the perspective methods, the case has led me to consider perspective through the example provided by Paul Klee's perspective

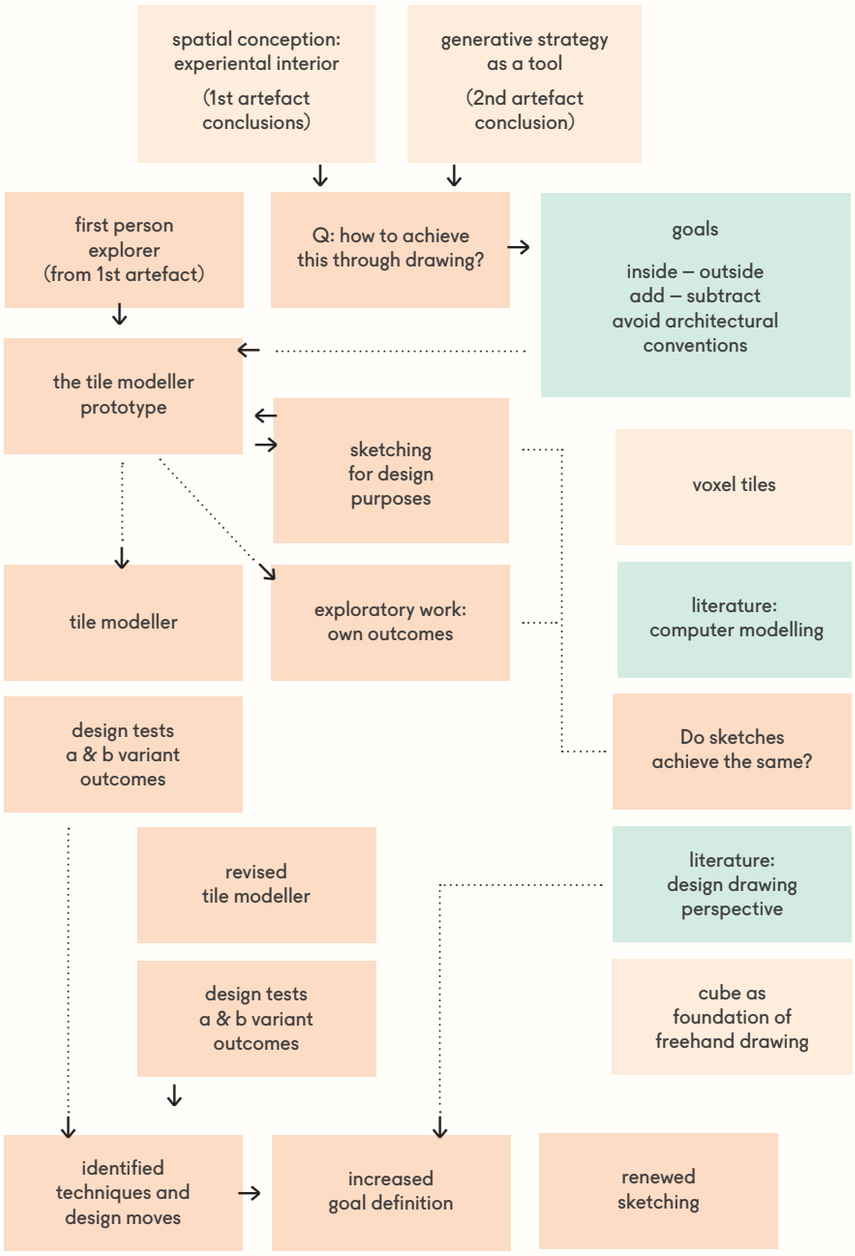
Figure 69

drawings, as a built rule for devising frontal views that emerge through organized tracing on a paper surface. Using the frontal perspective helps rid the illustrative burden of more complicated drawings, yet allows perceptual interior views. This provides a setting where drawing the spatial forms can be explored effectively and outputs can be utilized in more conventional design-oriented drawings. The drawings become juxtaposed with computer output that can show things and environments that could not be as easily produced with a pen, provoking further goals. (Figure 69). It may not be ever possible to fully emulate in pen-and-paper drawing the unburdened compositions achieved through the computer output, but this would be to miss the point. The drawing skill, although influenced by the experience of building the software, need not follow the exact same route as exemplified in the computer drawing. It can be allowed to develop into a different direction.

The other angle here has been to discuss drawing and modelling tools as contribution to the wider repertoire of design knowledge. This started by asserting the status of design images as sufficiently solid knowledge on basis of their perceptual interpretation. Putting forward ideas about how to produce such images are knowledge contributions. The methods discussed may not work as overall design approaches, but they should not be relegated to just to that of assistive tools either. A complete design can emerge from the application of the drawing method. The limiting cubic structure was permissive of ideas, perhaps even productive to them in few cases. The material collected from other designers shows that different software versions suggested different ideas and ways of working, even in a time constrained context. Just as the need for a method is recognized in the rapid situation of sketching, the need, affordances and limitations of drawing in these ways has to be recognized as a feature of the broader design process.

Figure 70

The progression of artefact three. The concepts that arose from the previous two artefacts strongly influence the direction this work took initially.



5. Looking back: A Design Credo

The design tool cases that were built have been discussed from their respective premises. The overall development of the tools is taken as a trajectory of the progression of reflective thinking. Each artefact and its associated literature are taken as components of the practice-led research process, where exploration suggests further moves. The process is interpreted as personal theory building. The three artefacts form a chain which has been advanced skills and understanding from three different angles, supporting each other.

"One particular kind of analysis is the examination of a work with a view to the stages of its coming-into-being. This kind I call the analysis of 'genesis'."

– Paul Klee, 1921 (Klee, 1961, 99)

5.1 The three artefacts as a journey

The previous chapters have described the three central artefacts as significant design cases within a research project. The artefacts represented three different angles on design, and have provided the project with research material. The initial grasping toward an overall theory of space through visualization has grown into an understanding of the designer's conceptual toolbox and the personal theory building process. This conclusive chapter paints a picture of the process that has taken place during the project, and involves the identification and delineation of a trajectory within the larger journey and its significance with respect to the research aims.

This longitudinal process of building the artefacts has an origin and a terminal state. The artefact chapters focused on reporting how each artefact was built, but here the discussion addresses the trajectory as a whole.

Donald Schön (1983) offered terminology and a tentative framework for practitioners to engage into research, including the concepts of reflection-in-action and reflection-on-action. Here, these concepts have been elaborated using John Dewey's description of reflective thinking as a consequential process driven by intent (Dewey, 1910). The practice-oriented researcher reports on the longer process and the development of the thinking involved. The thesis demonstration is both in the work and the writing, whereas the exposition of the analysis is in the text. The temporal progression of the development is reported more or less explicitly, as in some cases, the role of the artefact outcomes take a more central role. For Schön, one central way for practitioners to research involves building a personal repertoire of skills and contributing to a shared repertoire from which examples can be derived (Schön, 1991, 315–317). The practicing researcher reports on the thinking and problems that characterize design cases. In this way the practitioner adds to the growing number of insider accounts that arise from his or her field. In this thesis, the context has been university design research, where a practical design approach has been utilized in an inquiry about design tools. Schön's ideas are as useful in this kind of practice-led research, as they are in a professional practice. The central challenge for both the individual practitioner and a community of researchers is the selection of the matters to be reported, especially as regards what could be called the "thinking". Schön's concepts of reflection-in-action and reflection-on-action can be used to differentiate aspects of the practical work. Introducing tools as designed objects stimulates the reflection-in-action,

whereas the reflection on the past action is used to build a coherent interpretation of the cases. The work and its evolution during the course of action ought to be taken as a significant part of the reflective thinking process. The identification and interpretation of anomalous moments, exceptions from routine work, and other decisive moments constitute the main focus of the reporting.

At the same time, Schön encourages reflection and reporting that extends beyond the single work or a single problem. This crucially differentiates the report of one design case from a long view that attempts to identify where concepts come from, how available tools influence and guide work, and what sources contributed to the formation of the outcome. Does the researcher have a tendency to connect to philosophical ideas or to design precedents? Does inspiration play a key part or is the approach based on a more rationally planned approach? Questions in this vein are unlikely to be answered through reflecting on a single case, but are of more general importance for design. In this respect, Dewey's concept of reflective thinking (Dewey, 1910) is helpful in further elaborating the trajectory. In everyday speech, "thinking" denotes the inner monologues and imaginations that go inside our heads (Dewey, 1910, 2–3.) It would be a mistake to see these musings as the central matter for reporting. Active experimentation is crucial to the process, instead of just mere passive observation. Reflective thinking is stimulated by challenges and problems. It is a process where different aspects of the matter in hand are weighed, and evidence is summoned when required. Dewey identified components in the process of completed reflective thought. This involves identifying the problematic situation in the first place as a felt difficulty, defining or locating it, seeing profitable directions for inquiry, selecting appropriate evidence and forming conclusions. (Dewey, 1910, 72.) In Dew-

ey's given examples, the thought is an extrapolation of definite, observable occurrences, an inferring of the unseen from the seen (Dewey, 1910, 68–71). Although Dewey's formulation is more apt for a clear problem state that requires clarification, according to him, even an artistic exploration proceeds under a similar logic. Instead of definite problem states, there are felt difficulties and challenges to overcome. A similar instinct guides the practitioner along the paths that these difficulties suggest, and through trial and elimination the artist further develops his or her credo.

Examining the significant junctures in the overall research project then becomes here the main task for the researcher. Building the three different design tool artefacts has brought different concepts into focus in conjunction with the theoretical literature. The work with artefacts coupled with review of the related literature informed the subsequent work in a way that ultimately allowed the initial problematic to change shape and become understood. The cycle of making and guided reading is a major approach in practice-led research. The deliberate examination of the chronological development of work is present in Nimkulrat's thesis work (2009). She presents exhibitions as important milestones within the evolving process of the research, distinguishing between work and literature reading phases during her study. The progression has also been visualised in graphical tables. Mäkelä (2003) made retrospective reflection an explicit and central part of her thesis. Later, she has presented such progression as a spiral dialogue between the art and the research parts, held together by the research questions (Mäkelä, 2009). This cyclic approach has been adopted here, but it has not been woven around a single material medium, exhibitions or a genre of artworks. The broad category of design tools has been approached via three different entry points. I have given my thesis a clear structure that corresponds to the chronological development of the cases. Here it has been observed that the different artefacts suggest different topics in literature, which also permits the other artefacts to be viewed from new angles. I have been wary to strongly separate the making and the research, presenting the entirety of the thesis as research. Nevertheless, the work on the artefacts and the literature reading can be viewed as separable components in the research. The explorative and tentative design work is part of the experimentation, whereas the outcome artefacts exemplify and illustrate the ideas that have been worked on. Design tools or conceptual artefacts is a very broad category and can take many other forms than that presented here. The three artefacts and the abandoned directions are an expression of the author's personal interest.

5.2 Tracing the personal theory development

The artefacts presented in the previous three chapters are here reviewed as a part of an on-going progression. Each artefact case came with provisional conclusions of their own. These concluding states are the points where further pursuit and development of the same artefact began to seem unprofitable. New puzzlement and redefined questions were springboards that motivated further work. When the material work on an artefact and its use is finished, more distanced reflection on the past case can begin. Each of the artefact cases are recognized as separate, which to some extent guides the

interpretation of the artefacts for the research project. This is possible even when the production of the artefacts overlapped. This cross-influence between the artefacts has been discussed in the end and beginning of the case descriptions. The following collects together the story of the artefacts and their contribution to the overall personal theory development.

First artefact: Computer visualization as a personal theory of space

The first artefact was a computer visualization of a view cone in a plan view. Instead of a static picture, it was possible to move the shape and to build time lapse sculptures out of it. The shape is derived from accumulating view cone shapes on top of each other, using the plan drawing as source material. The ensuing form can then be viewed as an on-screen object. This was the point when the design experimentation changed into a conscious attempt to grasp a theoretical concept. In this case, a designer's "theory of space" was pursued by the means of computer visualization. This provided the impetus to begin a research project. In the beginning, the visualization was a design object with no explicitly stated aim of building a theory, personal or otherwise. Yet it did not appear satisfying to let the visualization stand as an outcome. The initial challenge was in finding an interpretation for the artefact. Soon enough the project provoked thoughts and questions that required a more concentrated research approach informed by the relevant literature. At this point the goal was to visualize the dynamic nature of the experience of space, underscored by a vague aim of stimulating thinking about the role of representations in the design process.

What is more consequential for the project was that the motion sculpture encouraged reading of literature related to perception and experience, such as Gibson's ecological theory of perception (1986). The first instinct was to see space as something that cannot be exhausted or determined through geometric descriptions, no matter how sophisticated. Yet an interpretation of Gibson's writing suggested that some aspects of the spatial experience remain fairly straightforward. The overall research task benefited from this streamlining of the understanding of space and spatial images. Although at the beginnings the first artefact might be perceived as nothing else than computer-generated visuals, it stimulated my interest towards questions concerning experiential aspects of space. Any designer might at some point become concerned as to whether his or her notion of the objects of design might be too static, and the first motion for making this artefact should be seen to reside at the point of such maturity. My tendency to see space as big furniture or a collection of co-located objects was challenged by the newly produced work and the literature.

The visualization became to be seen as a too cumbersome object to have any bearing for design. For me it did not seem reasonable to search for one-to-one correspondence between elements in the visualisation and some design outcome. Yet, at the same time it did not seem credible that a designer would work without some preconceived notion of what space is. This was the initial riddle and puzzlement that prompted to turn the design project into a research project. The work was promising in that it showed that it can be useful to engage in a theoretical topic through making design objects or visualizations, and I wanted to continue in this vein. The similarity of the visuals to illustra-

tions used by Gibson provided an initial link to the literature. At the beginning, the follow-up objects were envisaged as similar visualizations as the first artefact. This was explored through building variations of the visualization that would allow more direct interaction with the shapes. This came to be something of a dead end, provoking the exploration of a different direction.

The first artefact project suggested a number of directions and tasks that served as basis for the thesis research. The end of the case also marked a shift towards thinking about the role of the designer and the use of these visualizations as tools. As the visualization could not offer a direct route to design outcomes, the next step was to ask what is it that guides the creation of design outcomes and how self-built tools can relate to that. This required another design project, thematically linked to the first one. The notion of design tool entered at this stage. The issue was to find out how tools relate to design and furthermore, how self-built tools relate to personal theory-building. The vague idea of a "theory of space" as a possible research object dissolved and resurfaced as a notion of personal theory, a subjective belief about how to approach the design of space. The literature on perception showed possibilities for addressing some aspects of space as more foundational. The reading of Gibson provided an outline for what is understood by space within the thesis, as an encounter between an individual body and surfaces in the surrounding environment. The visualisation artefact became later interpreted in this stage-setting role.

Second artefact: Building a hand held design tool as an articulation of design moves

The second artefact made was a hand-held tool. The motive was to probe into the idea of tool in as direct way as possible, looking it as a hand held device, like a screwdriver or a wrench. This was partly a counter-move to the first artefact, which did not seem to provide routes to design action. Also, so far space had only been depicted on screen. As a contrast, the idea of going to sites and places and do activities there was attractive. After all, the work for the first artefact also had its beginnings in a real site.

The device failure at a test site proved to be a crucial moment for the research project, by showing the importance of sidetracks and dead ends. Substituting the digital sensor device with watercolours allowed the task to be executed as intended. Initially, the use of water colour seemed nothing more than a fallback option for the intended task, and only assumed great significance later. The incident provoked reflection of the concept behind the task, which was highly significant, and prompted questioning of why this one approach had been chosen, instead of some other. For instance, the same task could have been executed with a camera, yet this did not register as a favoured route. It was concluded that preference to making the colour slips manually reflected a personal credo, which I realised was more strongly present in the research project than I had previously thought.

The second artefact suggested a different literature and theoretical outlook than the first artefact. Here, no visual similarity between the tool and concepts in literature helped in building the initial connection. Instead, a conceptual similarity between the tool and topics in literature would guide the search. The design theoretical literature was valuable in clarifying what tools do within design activity and how designers build their thinking during design. It also became important to see design literature as central to

a design dissertation. Before the second artefact, most of the literature encountered concerned the qualitative experience of space, often disconnected from questions of designing space. I read and re-read the texts of Christopher Alexander (1963), Donald Schön (1991), Herbert Simon (1975; 1996), Bryan Lawson (2006) and Nigel Cross (2007a) in the expectation to learn about the generative design moves that now appeared central to my understanding of designing. In this way I built my approach around one specific concept within an otherwise broad topic. The identification of generative moves as the point of focus in literature review and in the experiments narrowed the topic towards more specific element in the design activity. The activity was also accompanied by a closer examination and recording of how and what guided and suggested the artefact's creation in the process. I could more clearly see the personal preferences at play, and also the way real constraints affect this process.

The second case marks a period when the notion of a tool was of central interest. The question of spatial design seemed to be best addressed through its design tools. This "tool phase" provided me with insight into generative moves, a well-examined concept in literature now confirmed concretely in my experiences. The tool in its role as a colour collecting device was seen to perform one rudimentary design move, a transformation. This concept could be applied immediately to past and subsequent work. The designer is able to employ a variety of material and conceptual transformations, the results of which can then be valued in terms of the designer's aims, interests and personal credo. As the concrete device was made to perform this one task, the tool angle became overplayed in that setting it to perform such a narrow task seemed to prevent other angles altogether. At this point, design tools were seen in terms of the generative moves that are played through or with them. This interpretation of design suggested that diverse tools and materials could be discussed in these terms. Even though the object itself could be appropriated for a variety of purposes, it seemed more worthwhile to start examining a more pliable tool through the concept of design generation. The concept of generation allowed to question the distinction between computer-based and non-computer tools, and also break my implicit and unarticulated assumptions about the utility of the tools. As the work on the second artefact became in this way exhausted, there was a need to explore another direction through building the third artefact. I now wanted to address the direct shaping of space through either drawing or modelling. Armed with the concepts I knew to be relevant to my quest, I was eager to go back to drawing and perspective, issue which had already occupied my mind during work on the first artefact.

The second artefact chapter illuminates the format for the tool-building process as a means toward reflection and personal theory building in this thesis. Design moves became to be seen as a narrowing act that propels the design forward. Invented rules and suppositions also impinge on outcomes, just as a choice to use a perspective method on a pen-and-paper drawing does. There is a personal view in choosing which approaches are desirable or interesting. In making the object and using it, numerous smaller decisions come to be made, revealing the way for further work. How these choices, small and large, become played out can be connected to a broader world view. The identification of the generative move and the path that would follow became more clearly in sight when building a tool as a definite object. This seems more effective than trying to think beforehand what one might believe design to be. Through building and use the articulation of one's personal credo emerges, and the generative properties of a tool cease to be meaningless, as the

moves are weighed by expectations and anticipations through growing familiarity, skill and trust in using the moves.

Third artefact: Extending design drawing skill through tool-building

The first artefact helped in framing a conception of space used throughout the thesis, whereas the second artefact addressed design tools from a generative angle. It felt an appropriate time to consider devices for proposing designs, namely drawing and modelling. For me, drawing was an already established skill, and now I sought to extend this skill through the understanding gained from the two previous cases. The third artefact represents an attempt to import elements of drawing to computer software and to bring in the work done on the first two artefacts. The software enforces a first person view of the model space, which is made of cubes. The cubic bricks are manipulated in ways that resemble drawing. The viewing angle can be constantly altered as the model is being built, and the moving view is also an integral part of manipulating the cubic structure. The choices regarding the view manipulation were influenced by questions about motion and perception that had arisen during the first artefact case. Free motion around the sculpted matter is an influential part of the physical modelling experience, and the virtual counterpart on the computer screen seeks to imitate this experience. The fluidity of motion in first person video games was taken as a benchmark for assessing the quality of the software's first person motion.

During the making of the software, the software itself was used to produce preliminary outcomes. Additionally, pen-and-paper drawing was used extensively during making, as it was necessary to visualize not only desired outcomes but also thorny programming problems. A certain mismatch became apparent. It became clear that I could actually draw the kind of spaces I was hoping the program could achieve, and the question then arose what was the program worth? This could be called a definite moment of surprise, when experimentation yields a surprising situation, which provokes "reflection-on-action", as described by Schön (1991, 56). Following reflection, I arrived at an interim conclusion that the program had less to do with perceived utility or the possibility of achieving novel form. The program was initially built for exploring space in a way that I was unable to do through pen and paper drawing. This way, a goal had become set for my pen-and-paper sketching, almost unknowingly. Having a goal here means to identify in more definition what will be sought from the sketching process. The software not only provides outcomes but motions and actions that could be thought about as exemplary for the drawings. The making of the tool was a continuation of the examination of the role of cube and a geometrical rule in a drawing, which was found to be a major element in the perspective methods. The same idea found a different expression in the drawings and the program. In this way, the program showed me a way to look at my drawing, in order to enhance my understanding of it. The artefact building had come to highlight a goal I had identified as current and pressing in my sketching process, and the feedback between making the tool, using it and using drawing all became ways to explore the issue. Deliberately exerting or extending one's interest is done to a point where a step back must be made to integrate the things learned back into the process. Putting the

learned things back into the drawing skill was crucial,as otherwise the new things would remain formalisms which would be "applied" in a design process, a doubtful premise.The designer's repertoire of design moves contains both explicit methods, tools, but it is coupled with the kind of knowing that is not as easy to transmit through written word.

The literature on sketching and drawing does not go much beyond Donald Schön's statement about design drawing as a kind of reflective conversation (Schön, 1991, 76–78). To get into the specifics I was looking after, I read perspective method books originating from designers and architects regardless of whether these were intended as academic research or not. The methods as a way to advance one's drawing skill, related positively to my understanding of what a design tool is. To me the perspective method literature, written by designers, appeared to satisfy what I was looking for: descriptions of self invented rules for drawing. With this in mind, examining Paul Klee's notebooks (1961) also proved valuable, as a demonstration of organising principles for drawing, not just perspective. The perspective method manuals for designers (Doblin, 1950; Pile, 1989; Lockard, 1982) stress that learning the rigid method as a way to learn free hand drawing, which is more useful in practice. This skill is achieved through learning to draw principal elements, such as cubes. The books supply one model for the reasoned organisation of drawing that does not prescribe a full method of approach, and the drawing can be still allowed to lead. When working generatively, drawing and physical materials are arranged with some guiding principle. The paper surface affords certain kind of drawing over others. Drawing, as Paul Klee's example showed, is flexible as it allows the creation of organic rules that can be adapted on the fly. There is no absolute free form, even if the organization may not be very conscious. For example, randomness may be chosen as a principle in drawing, but there will be an overall field within which the randomness is played out. In this sense there is no escaping some kind of organisation or a rule, resulting from the first choice to use pen and paper.

Inviting other designers to use the tools, as a complementary approach, has also provided insight. These situations put into question how the artefacts might transfer knowledge or suggest ideas to others, just as the perspective manuals did. As generative frameworks, tools give directions for producing outcomes. The work with other designers created a situation where the tool could produce discussion in a broader setting, even if artificially. As the artefacts arise from personal considerations, they can elicit interest and fascination in some, but easily arouse suspicion and reluctance from others. This suggests people have very diverse attitudes, highlighting the personal nature of the tool. The tools in themselves provoke thinking and critique, just as design objects or artworks would. Also, building the setting where the tool use could be demonstrated provided another point for reflecting on my research. The task formulation forced the outcomes into very condensed, almost primitive design processes, which could be chronologically reviewed. In this rapid setup, details such as the features in the view manipulation proved to be important for the formation of the outcomes. Looking back at my cases I could see, even if only metaphorically, similar forces at play. When building an artefact, elements of past activity could subsequently come back "into view" and reacted upon. Much of the work on the three design tools had emerged from first actions, the consequences of which needed to be managed throughout the cases. When beginning to report on the three design cases, I could recall the experience of the third artefact outcome collection as an example.

5.3 Overview of the practice-led research process

The above has described three cases of building artefacts and summarized the way they related to the advancement of the research project. Each of the artefacts have been interpreted as having informed the premises of the one that followed. They either influenced through the experiences they provided or through the literature that their building suggested. As has been mentioned, this process is not strictly a linear chain of cause and effect as earlier causes and effects accumulate, for example, the first two artefacts both contributed to the third one and the framing of spatial design tasks within perception is heavily present in the third artefact case. Likewise, the interpretation of the modelling artefact and the drawings was coloured by the experiences gained from the second case, which supplied the idea that tool and rule building and generative moves are important to design activity. The later work also supplied means for interpreting the previous work, although the design work had ceased. The second artefact case, interpreted as series of generative moves, gave the central design theoretical concepts that could be used for examining the first artefact in retrospect. The third artefact supplied examples of short design doodles, made with the software, each of which had a clear beginning and end. This encouraged a look at the past work and the hole project in similar terms, even if only at a more metaphorical level.

Focusing on one's own long process allows a very intimate look into the way tool building may become a part of personal theory development and a practice-led research process. Looking back is a matter of tracking influences and the associated thinking related to the different parts. There is no need to open up to scrutiny all details as potentially relevant for the later developments. Only the consequential elements in the project become important. The subsequent steps in the research process result from a long ges-

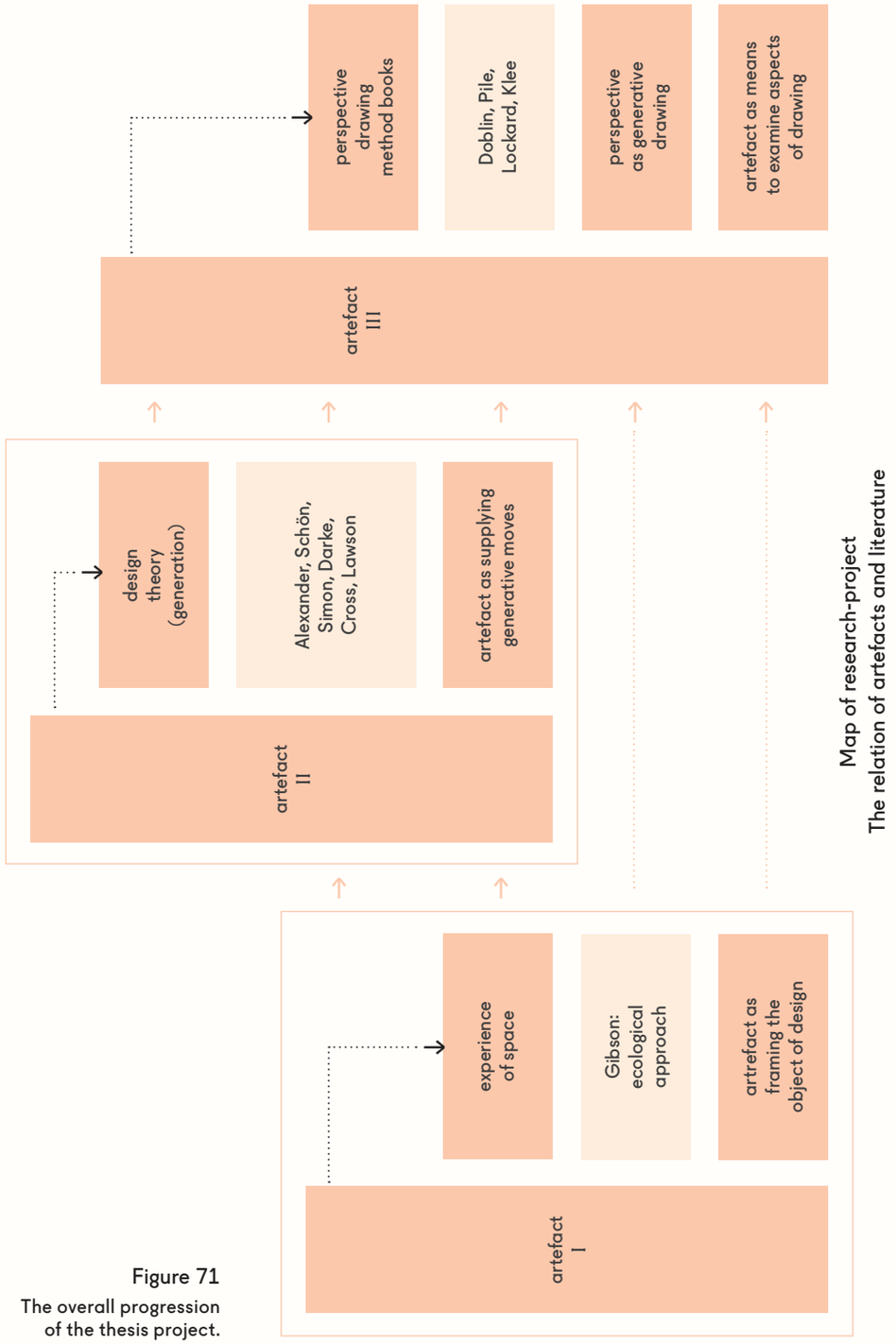


Figure 71
The overall progression of the thesis project.

tation phase where the artefacts contribution to the whole remains partly unclear.

The progression of reflection

The steps taken in the research project are shown in Figure 71. The artefact case parts can be expanded to the maps presented at the end of each respective chapter. The major blocks in the figure describe the project progression as beginning from the visualisation of spatial experience. This is followed by the hand held tool case and the process revolving around the modelling software. The associated literature is put in between the work and as resulting from the artefacts, although the processes are more parallel than the diagram makes them appear. The diagram should not be taken as a model for planning a research project.

Figure 71 (p. 219)

In Schön's terminology, exploratory and move testing signify different modes of practitioner's research (Schön, 1991, 145–147). The move testing consists of a more definite experimental activity loaded with expectations, whereas the exploratory mode denotes less definite goals of "what if" proposals. This does not mean that the exploratory research ought to be seen as aimless or random, as it is certainly motivated. Learning to conduct exploratory research effectively involves skills, and one can reflect on the development of these skills. The choice and motivation to explore certain topics instead of others is part of the logic of exploration and reflective research. Retrospectively, the first two artefacts appear to have had goal-setting functions in the process, but these goals remain somewhat vague or even ill-defined compared to the third artefact. The goals

revealed themselves much in hindsight, and required reflection on the process. The first artefact, geometries of the cone of vision and the associated readings of literature provided ground for a cluster of new approaches, most of which were rapidly abandoned. This feeling of a dead end, understood only intuitively at first, was shattered deliberately by starting a new project of building the hand-held colour collection tool, the second artefact. This alternative angle was formed through building, experimenting with the tool, and reading design theory. This helped to see the designer's tools in terms of conceptual, generative moves, which arise from personal preferences and what could be called a personal theory or an artistic credo. Following from this realisation, the building of the third artefact, the modelling tool, was instrumental in directing learning acquired in this building process towards the more focused topic of sketching space and form. The basis for the third artefact was the understanding that drawing and sketching form also involve the building of tools as drawing rules, and that the concepts and theory that arose from the building of the first artefacts, could be used to dismantle and analyse my own manner of design drawing, identifying the current and pressing goals in a process that extends from and beyond the actual thesis project.

The overall project demonstrates characteristics of a research-through-design approach. The artefacts are initially openings to a topic, but are also valid parts of the progression of reflective thinking. Each tool was different, but on a more general level the act of theory-building becomes repeated, merely viewed in new light. The overall process of artefact building is a way to bring cohesion, deliberation and organization into one's own personal theory building. The lessons learned from the artefacts could also be fed back into the more established habits of drawing and modelling. This is how to engage in Schön's reflective research,

a purposeful activity that enhances the process of reflection-in-action, exercised in the medium of sketching. Some things are so directly understood that grasping them does not require reflective thought, like the common objects in the environment. Scientific concepts like atoms and molecules are abstract to the layman, whereas to the educated scientists they are already quite concrete (Dewey, 1910, 136). Dewey describes the acquisition of new meanings as a constant spiral movement of knowledge (Ibid., 1910, 120) where foothold is gained by basing the new on that which is already understood. The artefact building process is a way to begin bridging this borderline so as to claim new terrain for the known. The borderline of the known and the not known is the home of reflective thought.

Challenges in reporting

For a project that contains many artefacts, each with numerous offshoots and ideas, each of which could be potentially pursued further, it is difficult to choose what to report. Each case involved alternative directions for development which were not fully realized as outcomes, but usually tried out in some tentative form. The artefact chapters have described the ways in which these emerged. In a situation where these explorative steps were not followed with further development, they have to be regarded as dead ends. This does not mean these experimentations are meaningless. On the contrary, without them the courses that were ultimately taken would not have been taken. The dead ends were here reported to the extent they have been meaningful in the reflective thinking process.

Different meanings or interpretations of an artefact can be tried out without actually creating new physical objects. When reporting design cases, this occurrence of new tool interpretations can be a threat to the integrity of the description. After a thing is made, there is an opportunity to see it as something else. The understanding of design in this thesis follows the notion that materials, tools and objects may not have a definite means-ends role within the design process. The designer can deliberately invoke viewpoint changes, inversions and other conceptual moves which may even radically twist the interpretation of the whole work. This is part of normal design activity, and usually the artefacts became fruitful only after they had been reframed as something that they were not originally envisioned for. This might even happen multiple times. As the designer can use found materials and objects as basis for design, she also "finds" her own work anew. For the designer, there may be no reason to stick to the original intention, if the new avenue seems more fruitful. In a research context, care should be taken when this kind of reinterpretation is found to occur, as it can pose problems for reporting. The newfound interpretation may be presented as the original intent, which would be untruthful. But it may also be argued that describing a long chain of developing interpretations can threaten the consistency of the reporting and make for incomprehensive reading.

My solution has been to provide accounts of the major re-interpretations and abandoned directions, in as much as they have influenced the later work in some way. This also requires interpretation and is by no means simple to decide what to describe. The development of a spin-off from the artefact can become quickly abandoned as during the course of making it appears unnecessary, not fruitful or leads to otherwise undesirable directions. For the artist, a move might appear false, indicating a straying from the path of the in-

ner logic of the artist's credo. This is when a tentative outcome work does not adequately represent the goal or meet the standard the author has set for himself. Other reasons to abandon spin-offs are the time-frame of the project or real-world physical constraints. This role of research project as supplying constraints or generative bases for the designer may appear artificial or downright strange. For those established artists and artisans, who work consistently with their chosen materials, this may be easier to avoid, as they can continue working according to their creative credo. To me, the process has been loaded with uncertainties, and in such a situation the practicalities of the research setting may feed back into the making process. Then it becomes a question of how much to write about the frustrations encountered by the researcher during the research project. Although the frustration stems from the real situations, it is not necessarily relevant to the research topic. I have remained moderate about using this device, trying only to convey the "felt difficulty" that led to the creation of the artefacts, but not necessarily all the difficulties and frustration in building the tentative interpretations of the tools that followed after the design work. This is mostly allowed to come visible in the main trajectory of the work, as the three artefacts can also be seen as stepping stones towards a more refined interpretation and understanding of one's personal approach.

Reflections on the practice-led approach

The thesis has described a process where different facets of the personal repertoire and skills have been extended through tool-building. In this sense, the personal theories are skills and beliefs that have been articulated through the reflective tool-building process. The three tool-building cases ought to be seen as addressing three entry points towards articulating and developing the repertoire of personal theories and skills. This thesis contains a written report of the making of these tools and the interpretations that ensued from the reflection on the work. In this practice-led project, the thesis project became an account of the ways a designing researcher builds concepts that allow and suggest further design. This process has much subjective elements in it. Any other designer might have found different routes from the initial starting points. Challenges arise when separating the more subjective elements from that which is generally useful, inspirational or replicable by others.

Repeating a process of building a tool in three different ways has offered enough material to provide some overview into what to share of an understanding of such a process. A recurring tendency in this project was that as an idea came into being it was built into computer tool. Later it was possible to make use of the idea without this definite piece. Each concrete design artefact became a stepping stone also in this sense. An idea about the perception of space was built into a digital sculpture, but later remained a conceptual idea influenced by readings into literature on the topic. The second artefact, hand-held digital device, broke down during a test and showed that ultimately the same process could be achieved in traditional means, provoking the thinking on the underlying concept of a designer's tool. The third artefact derived ideas from drawing into modelling software, but turned out to be more instrumental in clarifying self-reflection associated with drawing.

I have already discussed Polanyi's concept of interiorization (Polanyi, 1966) in conjunction with the skill elements in the third artefact case. What I have found valuable is the idea that attempting to dismantle one's skill into its components fosters paralysis at first, yet after this obstacle is surpassed, a route may open up for improving the skill. For Polanyi, the components are the tacit particulars of the skill that are normally out of conscious focus in normal skill use. (Polanyi, 1966, 18–19.) The presence of a skill has been easier to ascertain in the third artefact case than in the prior ones, due to the more contained nature of drawing skill. Yet something similar happens on the larger level of a practice-led research process. Building a new tool highlights the way the designer engages with a material or a conceptual idea. At first the idea is made simple, through the necessity of building it in some material form, but later the idea grows to be a more conceptual understanding of the topic. This does not mean all important knowledge in this project has been skilled and tacit. The benefits of making the artefacts are not wholly returned to some ineffable skill. The explications can be later summoned if necessary. The artefact building itself is an act of embedding personal theory or concept in a tool or other material object. The explication through concrete making affords a more definite object for reflection-on-action.

More broadly, making an artefact is also a way to establish and maintain direction for the research project. The artefacts anchor topics the researcher becomes committed to. There are also boundaries to what the artefact and the subsequent reflection allows the research to say on the pursued topic. It is often tempting to draw comparisons with the presented tool or technique with some other direction, but the researcher can only powerfully reflect on the taken route. Although I have attempted to paint a picture on how the generative tools reside within a broader panorama of ideologies and surroundings, these considerations are at the edge of what the three artefacts permit me to say. Examining these connections in more detail would likely require a different research approach.

The research topic is held together by a conviction that the different topics explored belong together and appear to me as a consistent whole. The chosen topics have populated my view of design during the timeframe of this thesis work, much like invented characters might populate a novelist's imagined world. The novelist puts his or her characters in new situations and begins to try out interesting outcomes and stories out of these situations, and the designer has a feel to whether the parts of the personal credo would belong together and form a coherent whole. This way the topics clash and communicate with each other, and the credibility of the beliefs is in a constant check in terms of the story they produce. This is the artistry and the skill of maintaining and developing the personal theory throughout the tool-building process.

5.4 Thematic conclusions

Besides demonstrating the research-through-design methodology in tool-building, the work also relates to the thematic areas present in the work. The artefacts were built to address questions about spatial design, design generation, tools as knowledge distribution and simply as ways to discuss the role of computer tools in design. What follows are the collected insights on these thematic areas, as they stand at the end

state of the research project. It must be again reminded that the research questions are a distillation of much more cloudy, thorny object. The argumentation is not a clear progression that would result in an outcome that falls "below the line", like a product in a mathematical formula. Instead, the thesis closure within these themes is in part similarly difficult to define answers, contained in the work done and its description. With this caution in mind, the concluding remarks on these themes in the work are offered as answers to the original research problem settings.

Notes on computer use in the personal theory-building process

As part of my design approach, I have incorporated computer software as basis for the artefacts. In this thesis, building tools is seen as a continuation of the tool building tradition within design fields like architecture, furniture, spatial and industrial design. Perspective drawing tools could be modified by the designer, as they are not black boxed to the designer using them as the computer programs are. Pen-and-paper drawing tools and methods were originated and modified more productively within the design disciplines, whereas the computer programs for designers are more difficult to accommodate to informal approaches. I have utilized my familiarity with computers and my programming skills to create prototype software, intending to get past this common obstacle. This has allowed me to explore material and forms in ways that would otherwise have been difficult. But I have not been satisfied with allowing the computer output to stand as the only design material, instead asking all the time how the artefacts have advanced my understanding and skills.

Loss of intimacy, nuanced tactile qualities has been offered as a potential threat of the indiscriminate use of computer use in design. Juhani Pallasmaa has offered that computer imagery flattens objects to what would otherwise be a multisensory and empathic relation (Pallasmaa, 1996, 12–13). In Pallasmaa's view this would be better achieved through physical materials than with objects on computer screen. Despite benefits, the earlier phases in design are most vulnerable to the effects of computer modelling, bringing in a false precision and erasing the beneficial vagueness characteristic of traditional materials and media. Furthermore, computer programs tend to dictate how designs are compartmentalized, suppressing the more organic ways that whole-part relationships are addressed. (Pallasmaa, 2009, 95–100.) Bryan Lawson too warns that overt reliance on photographs and quick computer aided modelling results in a loss of the intimacy that drawing offers (Lawson, 2004, 38–39). Thus, paying attention to the tactility and sensitivity of traditional mediums has become a starting point for overcoming these potential problems. Caroline Hummels (2000) examined computer design tools from a similar point of view, calling for more multisensory, tactile computer tools, where principal shape creation arises from nuanced hand motions.

In my thesis, the personal credo and the concepts that have fuelled the artefact design are not informed by questions of touch and tactility. Although I can to a point agree with the criticism of Pallasmaa and others, I'm not as certain that the problems would stem from lack of tactility.

Artistry and intimacy does not arise from touch in any simple, guaranteed way. Even prior to digital computers, various artists have sought to distance themselves from the most direct connection with their work, and this has not

prevented them from developing their artistry. For example, Man Ray related an earlier experience of painting with an airbrush, where the tactile qualities of an ordinary brush are absent – the device does not touch the canvas. He was thrilled with what seemed almost a "cerebral activity". (Ray, 1988, 67.) It is true that many programs are not as flexible as pen-and-paper drawing as a way of devising new rules, nor is the screen surface as nuanced as a piece of paper. When using ready-made software much of the burden and fascination of rule-creation and personal theory development are removed. To me this is far more crucial point to discuss than the question of whether computer programs are tactile enough. When making drawing software, emphasis should be on understanding generative qualities of drawing, and not replicating superficial aspects of draughtsmanship.

The key is to think about the intimacy and not the physical tactility as such. Malcolm McCullough, on the basis of his work on digital media and architecture, presented the concept of leverage as the significant motive for using creative computation (McCullough, 1998). Computer allows setting up situations where a small shift in parameters allows a complete recalculation in the computer model. Surfing this space of parameters can be thrilling, as the explosion of forms on screen can be made to follow the finest twitch of a mouse or finger. In as much as the parametric exploration can afford a kind of craft, as McCullough suggests, then the intimacy with the tools can be guaranteed. It is achieved through investing time and interest. For some designers, thinking and devising the rules and parameters may seem like the real meat of design. The exploration of the parametric spaces provided by the software may seem tame compared to that.

To me it is more important to consider rapidness, not as the speed of efficiency, but as something that enables different generative approaches. For example, rapid brushstrokes are an enabler of expression for an impressionist or expressionist painter, not a means for producing a high volume of paintings. In my design processes, I have found it acceptable if a program has limited output and lack of multidimensional tactility, as long as it allows rapid exploration and expressiveness of space. In this sense, the third artefact and its use is an essay on the properties of the three-dimensional "brushstroke" of the cubic volume. This was played off against paper-and-pen drawing, where a similar idea could be powerfully utilized. Rapidness understood this way is an important aspect of tools, and relates to the sensitivity and gestures that Caroline Hummels (2000) raised in her work. Some approaches and tools are inherently slow, and do not convert to a bodily skill, yet this does not prevent them from being useful to design. A computer artist might acquire a dataset, visualize it in a program, transform the data set and produce a new type of visualization. The required intimacy is to be found from the longer process, not from the draftsman's or artist's relation to a canvas. The rapidness discussed above does not play as large role in this approach. This is the larger picture of the kind of processes Sevaldson (2005) describes. On the whole, the second artefact project can be contrasted to the digital journeys he presents.

In this thesis work both the rapid, tactile and the slower process of constructing a project have been utilized. I did not want to explore design tools either as solely based on intuitive tactile relation or as distancing visual representations. Here it has been offered that the rigidity computers sometimes introduce to design may be initially helpful, even if the tool is later abandoned. What is common to the presented three cases is that each time as an idea emerged, it was made into a computer-based artefact. In turn, the concrete object was eventually put to background and the un-

derlying concept, now understood more clearly, could be examined independently of the artefact. Although the artefacts were not very extensively used after the motive to work on them petered out, they have remained meaningful in the later stages. From the perspective of personal-theory building, the choice to work with a computer brought in a need to limit the tool ideas into fairly small and manageable software pieces. Also, even if the software is modified it still remains as an enduring, definite version of the artefact. This definiteness helped in gaining a foothold for the more profound learning experience.

Spatial composition as a design skill

One of the overarching themes of the work has concerned the design of space, yet the work is not about a professional interior design or architectural context. Instead, I have attempted to discuss design in a more abstract way, and the artefacts work as means of accessing the research issues through designing. In this work, design denotes a set of skills and capabilities in utilizing metaphors, conceptual inversions and other generative means productively. When discussing spatial design, this approach concerns what could be called spatial composition rather than the overall task of a designer. For example, drawing has been discussed as a depth-perceptual box, a virtual environment in which compositions can be enacted, and not a way to deliver architectural illustrations. The way to deliver sympathetic, evocative illustrations in the manner of Gordon Cullen in his Townscape (1961) has

not been the objective here. The quest was launched in order to examine and develop an understanding of drawing, not how to draw well. I have refrained from suggesting ways to achieve good outcomes, good designs or environments. This thesis emphasises the focus on tools and tool development. For example, this means concentrating on how to achieve a good understanding of design drawing as means for exploring a spatial composition.

Having said this, the artefacts have been loosely styled after common tasks in spatial design and architecture. The visualisation of motion in space is about establishing an idea or schema for thinking about what space is as a design object. The visualisation described in the first artefact case was initially made as an alternative design representation to plans and sections, yet resulted from these conventions. The second artefact, the hand held tool, relates to a visit to the site and the site as a source of design material, a common route for architects. Interior designers might build colour palettes and material collections from an existing site. Instead of using camera or rulers for gathering materials, a personal tool was built. The tool would then define the relation of the designer to the site. The third artefact was used to explore how drawing and modelling relates to generating spatial design objects and forms, and this compositional skill is related to design of objects and interiors. Perspective manuals for different design disciplines have offered different ways of drawing, and I have been examining this notion through exploring computer modelling, pen-and-paper drawing and their influence on each other.

The artefacts represent an angle to design that relates directly to building, modelling and drawing spaces. When narrowing design to this kind of laboratory of envisioning objects to be, the freedoms for proposing become different than in above contexts. The exploration relies more on cre-

ative imagining of what could be, instead of simulation or analysing a strict need-basis. This overwhelming "freedom" may also be characteristic to those art and design fields where independents and freelance designers can put forward new ideas. Tools, mediums and materials can initially give direction within this freedom, but so do beliefs and ideologies. Personal beliefs and cultivation of an artistic credo happens also through understanding the ways, materials, tools and rules can be put to play. Building the artefacts has been a process of clarifying and identifying a personal credo as it relates to space.

Historical studies back up the idea of subjective, even personal theory in spatial design and architecture. Design outcomes are not teased out strictly from material necessity or optimising conditions. Sixten Ringbom (1987) has meticulously traced the ideological background for the emergence of stone architecture fashion in Scandinavia at the end of the 19thcentury. Robin Evans (2000) has discussed how scientific upheavals inspired modernist architects to transform ideas about relativity and four-dimensional space-time metaphorically into their own work (Evans, 2000, 348–349). These are broader ideologies, shared collectively, and not merely personal theories. One could perhaps talk of local theories, movements that arise in a specific time and place. Such ideologies are vague enough to allow different interpretations. There is room for finding original and personal expressions for the idioms and manifests supplied by movements. In this way, ideology supplies directions for designing. History does not prescribe nor give full templates to designers on how to act. But it is clear that the aforementioned occurrences can be interpreted on an individual level. The designer's building blocks for personal theory have been picked from various sources and developed through work and reflective thinking. If the personal theory relates to space, the designer's spatial conception becomes played out each time spatial form is generated. Transferral of concepts from other fields supplies ideas and new ways of framing the spatial design object. These become played out in drawing and modelling. In this work, a look at a theory of perception has informed the building of the tools and the subsequent interpretation. The view taken here is that there is no one absolutely correct way to transform perceptual theory to form a basis for designing, and as presented here this transformation has been largely an interpretive process.

It should be stressed that these ideologies or personal theories are not complete systems of thought that reside within people's heads. In the practical cases during this thesis I have emphasised that the theories become both defined and played out through material, visual and concrete means. Here the personal theories have been strongly associated with built objects, artefacts. Similar architectural theories and speculative, personal theory or spatial conceptions are also best viewed as made objects. As such they have a purpose in the designer's or architects building of a conceptual palette, both necessary and desirable for producing creative outcomes. On overall, the cases demonstrate the way I have built my repertoire of material and conceptual tools and increased my understanding of how to structure the spatial design task as generative processes.

The concept of generation in design and practice-led research

In this work I have both examined and put generative approaches to use. Generation has been examined here in relative isolation from things that professional designers do. The persistence of this term in literature shows that is a durable concept. Both Lawson (2006, 188–199) and Cross (2007a, 33) spend effort discussing generation in their overviews of design, seeing it as fundamental. These authors have attempted to show generative moves in the broader context of what designers do. Grasping the significance of generation, especially as a choice strategy makes it possible to interpret very diverse materials, tools and artefacts from a similar angle. The ability in employing and following through generative moves appears to describe an important aspect of design skill. Here generation implies in some ways a meaningless move, a neutral activity that results in an altered view or new material in a design case. I have attempted to be clear and definite about what the artefacts generated, both as tools and as objects within the research project. As such, the interpretation of the outcomes is enriched with material for inspecting the generation further.

The first artefact was guided by an understanding of generation as almost an exclusively algorithmic and computational notion, where the new, unexpected and rich geometrical shapes are generated from an existing plan drawing. I could see the connection between this and the way perspective methods generate a view from elevation and plan, but did not immediately see connections between this and the ways the artefact building utilized generation, or how the artefacts could be generative towards the research process. Seeing generation as more broadly useful term for inspecting design was an insight that came only later. But as this lens was formed, it was possible to reflect more on how the visualization artefact came to be. The visualization resulted from moves that in themselves appeared fairly meaningless, although satisfying personal interests. Then, after the visualization artefact had been made, the search for significance, meaning and interpretation truly began. This interpretive phase properly started when the activity was no longer a design-generative search, but had reached a terminus. This was instrumental for developing the personal theory further. The second artefact, the hand held tool, was seen as a means for producing new material for use in the design processes, derived from the intended site of a design outcome. The idea related to a site as an origin for design decisions, and building the tool highlighted such narrowing-down or constraining of choices. Some architects might choose the undulation of landscape and sunlight to be factors for rational decision, whereas others might interpret them more poetically. The generative act came to be understood as a choice, related to a personal design credo. As this was arrived at by building and interpreting a physical tool, the tool-building and materials were now seen as having generative potential as mechanized embodiments of this credo. The third artefact was used to explore cubic tile structures in similar vein, as a guiding principle in form creation that played part both in devising the software and in pen-and-paper drawings. Generative drawing could be separated from other drawings as something that does not have immediate, definite purpose for the designer. Drawing appeared a way that allows a vast richness of different generative approaches, ranging from the modifiable perspective methods, through perspective sketches to all-out scribbles and automatic drawing.

Birger Sevaldson's (2005) thesis on digital design techniques demonstrated how very complex computer tools, not intended for design, can nevertheless be useful for creative design. They are not prescriptive tools but appropriated in generative misuse strategies, visual thinking and longitudinal processes where the material becomes transformed

multiple times. I have also interpreted Caroline Hummels' (2000) work as an examination of the human body's principal generative properties, mostly hand gestures. Reading these works through a generative lens, the contribution in these works appears as the opening up of the personal design credo and the identification of the resulting generative approaches. To a degree, I have exercised an approach that differs from both of the above. The algorithmic processing of space and the hand held tool as a project is reminiscent of the generative algorithmic approaches exploited by Sevaldson. The modelling and drawing topics are closer to the directness favoured by Hummels, although I emphasise their role as design tools. Also, the second artefact, as a hand held device, links to the body as constraint on expanse of design information, as the device only allows colours to measured that can be brought into direct contact with the instrument.

The use of the specific word "generation" may invite opposition. It is not a term the artists and designers would necessarily use of their own work. Both the connection to the genius of the romanticists, and the generative algorithms of computational design, may seem undesirable to some and old fashioned to others. Not to mention biological or even biblical connotations. Klee's use of genesis is an example of the latter. What is seen as genius might be simply a matter of being trained or skilled in employing these generative approaches with consistent success, with ability to modulate the generative approach towards surprising results. Originality is manifested when outcomes are recognized as relatively improbable and insightful. For the individual these are personal discoveries that motivate further work, whereas the society at large may evaluate the originality of the outcomes differently. Although I have approached the concept of generation with a mind to removing or ignoring these associations, it might be better to embrace them.

Apart from the design approach, generation is a concept that a researcher can use to make sense of design work. In different forms, it is a common topic in design theoretical discussion. Paul Klee's *genesis* (Klee, 1961), Simon's design styles (Simon, 1975), Schön's generative metaphor (Schön, 1991, 184–187) and Darke's (1984) formulation of the primary generator, are all described as having an immediate function in how design proceeds. Paul Klee already offered the examination of the work's genesis as a mode of analysis that can offer insight to the maker. For the practice-led researcher, the concept of generation offers a viewpoint from which to inspect one's own design work, and to question and inspect the origins of the works. In this thesis, the idea of back-tracking the genesis of a work has also been used to uncover the personal beliefs that might underpin the material choices. More work could be done on the analogue between programmatic generation and other self-built rules as means towards further reflection. I can hope the present thesis offers useful material for seeing how the concept of generation could be made to work as part of an enduring process, especially as an element in identifying one's personal beliefs and how they guide one's design work.

Generation is a useful concept as it does not make assumptions about the structure of the design work, yet captures an important aspect of it. It is more resilient than, for example, attempts at generalizing about the temporal phases of design. Design outcomes may arise from studying a detail, or contrariwise, from an understanding of the big picture. The outcome can arise from conscious rational effort or merely recognizing something already existing as a design proposal for some other purpose. The material exploration can work as the generative impetus of the work, or likewise, drawing or working with a different medium can serve it. All these approaches encompass generative design moves. Here

I have refrained from theorizing about or modelling generation, but allowed it to remain a concept that gives coherence to the research task and the work done. The major purpose has been to focus the research on one aspect of design tools over others. Although this may also be understood as a personal preference, it pertains more to the choice of the research topic and its framing. For the practice-led researcher, intent on examining his or her own work, the lens of generation can provide an additional thematic for reflection. Being conscious of generative moves in one's work allows one to reflect on why the move or approach was chosen, bringing personal theory or credo into clearer light.

Tools as shared knowledge in practice-led research

To build a tool-like artefact is to believe it is somehow beneficial. The artefact remains a picture or trace of these beliefs. The practicing researcher has already experiences, premises and assumptions at the beginning of the work. Looking back at a series of tool design cases the development of this understanding can be better examined. Tools are also a concrete way to share ideas about how to design. Practical design work is an ongoing process, whereas a meaningful starting point needs to be established for the thesis. The three artefacts and the things done, in some sense, have their beginning already before the project. This thesis has reported a period that has significance within a longer process.

The process described in this thesis is the overall method of approach to the research topic. This can be compared to

other records of practice-based, practice-led research and research through design. In this work, the artefact building was crucial for fostering and evolving a personal design credo through excursions to previously unvisited terrain. Yet at the same time the new directions are built on previous knowledge, interests and skills. The accounts are reported selectively. As the artist lays the pen on the paper, it is not only the outcome that would be useful knowledge. Also, recording the pen positions would reveal little about how the outcome was reached in terms of initial choice. Many things pertaining to the outcome are not immediately present in the situation. Questions arise as to how was the skill of drawing learned in the first place, how does the artist usually approach drawing and how was the reasoning leading toward the outcome achieved.

This thesis is an insider account about designing and building design tools. There are advantages to this insider view as compared to studying the topic from the outside. The insider view permits the researcher to posit all activities in relation to a process that has been going for a long time, and to answer questions about the work origins. All this is not easily available to the one looking from the outside. The researcher can take advantage of this inside view, even if this positioning comes with its own limitations and threats. The artist reporting on her own work has to rely more on her own conviction that the influences reported are the significant ones.

Tool building and material exploration as a topic defines an important target within the larger scope of practice-led research in design. This allows an entry point to the design activities itself. The focus on generation and conceptual tool-like artefacts has a different nuance compared to a project where the objectives are related to artistic or design outcomes, such as paintings or consumer products. Tool-building

and distribution is not a novel idea for sharing knowledge and skills. If the perspective method books deliver meaningful points about design drawing, the books can be seen as a rudimentary model for distributing personal theory and knowledge as tools. After all, the manuals were created by designers and modified to suit specific needs in different design disciplines. Practice-led research into tools can serve as a model for engaging into similar activity across wider range of topics. To be of wider application, this idea requires a framework for discussing conceptual tools and not merely drawing devices. In this work, I have examined tools from a generative angle, which supplied the framework. In light of the theoretical literature and the experiences I've had, the ability to deploy and manage generative activity appears a significant design skill. As discussed above, the concept of generation, as a strategic choice, helps get further into explaining moves that might become hidden under the terms of inspiration, intuition and influence. The adoption of a generative approach is not always conscious, but often the forking of choices and abandoned routes can be perhaps identified afterwards. The focus on generation and the generative strategy has been useful in reviewing one's own past design activity from a consistent angle.

One model offered here is that the engagement into a tool building is a kind of self-imposed contract. Because the tools are elevated into designed objects themselves, the artist or designer is more inclined to continue and finish the tool, at the same time building an understanding of its significance. During this process learning and insight occurs. When discussing more flexible, ephemeral tools like drawing, it is not easy to delineate the borders of such a contract. Building the tools into physical objects distinctly outlines different aspects of the ongoing process and helps concentrate reflection on definite things. Presenting this as something shareable has been achieved here mainly through writing about the work done, accompanied by the illustrations throughout the thesis. Part of the knowledge that is exhibited in the making is more akin to craft skills and cannot be immediately attained, but the route towards developing these skills can in turn be explained. The more overarching process becomes the replicable element that can be emulated or compared. Others need not attempt to build or use the tools presented here, but to consider the possibilities of what such a building process might entail.

5.5 Conclusion

This dissertation has discussed personal theory building based on the making of design tool artefacts. The project originates from an interest towards drawing, modelling and computer tools. The thesis has reported a chain of design tool artefact production as a process, where each tool and its use informed the further reading of theory and the subsequent tools. The process demonstrates a way of cultivating a personal credo through designing new tools and conceptual artefacts. The writing in this thesis has aimed to describe the artefact cases in a transparent manner, revealing the initial seeds for the projects, how the outcome emerged from actual construction and how the conceptual role of the artefacts came to be interpreted. Instead of concentrating on iterating a single artefact, I have chosen to launch three different directions, each of which has a bearing on the overall themes in the work.

Personal beliefs, ideologies and guiding philosophies are a recognized part of design theories. Donald Schön's view of the reflective practitioner also acknowledges the subjective parts of the practitioner's beliefs and knowing-in-action. The approach presented in this thesis has focused on the building of tools as a way to forward reflection through a successive chain of tool-building, where each of the tools has provided further reflection and also afforded new interpretations to arise on the past work. Looking back at the whole process has provided an outline of my overall understanding of designing. The work and the discussion has also provided a viewpoint from which it is possible to pose questions about what is the status of design work as research output, either as written or in the produced design outcomes. Built tools and rules as personal guidelines can also have the role of a design output. If the personal theory is the closest conceptual layer from which the designer draws his choices and decisions from, discussing these personal theories ought to be of high importance.

In research approaches where design and creative work are used to advance the research topic, the utilization of tool building for these purposes has been less discussed. In this thesis, I have demonstrated one way of building tools to direct the reflection on designing itself. By presenting three different cases, I have been able to show that the reflection can be directed to various aspects of personal theory building. On one direction, it has related to the framing of what space is, secondly, as a means to highlight what a design move is, and thirdly, as an extension to an already existing skill of design drawing. In the research process, I have also demonstrated how these topics have fed to each other, both as a chain of developing new tools but also as a way to build further interpretations of the already finished works.

The presented thesis ought to be useful for those researchers and designers who see themselves in a similar position. By initiating a tool-building process one can embark on a journey of discovery. At the same time the exploration results in tangible outcomes that can be appreciated and examined on their own right. The literature, thoughts and occurrences in the design process have provided material for furthering the study. Here the project involved different, yet interlinked artefacts, between which the theoretical premises and the personal beliefs become altered and adjusted. This setting has provided possibilities for examining the connections between the different artefacts and the ensuing overall reflective thinking process. Altogether, the works demonstrate the building of a thematically and conceptually robust continuum, an emerging design credo as a repertoire of skills and beliefs.

Practice-led research gives a broad framework for connecting creative design work with theoretical topics for the benefit of advancing both. This is already an established theme in design-oriented theses. Here it has been offered

that putting emphasis on the process, multiple angles to the topic, and the long period of time that such a project entails would provide a comprehensive setting for such work. The idea of tool-building fits well alongside research that presents finished products or artworks. The thesis has on occasions used perspective manuals and guidebooks for designers variously as a metaphor and a concrete example of knowledge produced by practitioners for practitioners. I liken my work to the kind of discussions in the perspective method books of old, from which I found inspiration even before I set out to do research. As an advocate of a practice-led research approach, I feel it is important to be aware of the more practical literature on their topic, even though it may not always arise from an institutional, academic research context. If the boundary between academic theory and practical knowledge is dissolving, it means discussing the practical outcomes as valid knowledge. Tools, methods and sourcebooks bridge present-day academic design research to that which is interesting and worthwhile in past studies within these topics. Artist autobiographies, personal theories and manifestos could be examined for their knowledge contribution, not merely as historical artefacts but templates and inspiration for new contribution types embedded in a practice-led research framework.

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Abstract

Design research has traditionally sought to include creative design activity as part of research. Especially approaches such as practice-led research and research through design seek to strongly base the research on practical design activity and skills. This thesis presents a practice-led research project on the topic of building design tools. The emphasis is on creation of design tools as a vehicle for advancing understanding and reflection on designing, the personal theories and beliefs that form part of the designer's credo. This has been approached through building a series of design tool artefacts. Three cases are presented, each allowing a different angle to the topic of design tools. The first artefact is a computer visualisation that illustrates the shape of person's potential view from location as a graphic shape. The way the artefact frames visibility for design exploration becomes influential for the subsequent artefacts. The second built artefact is instead a hand held tool that uses a colour sensor for recording colours from the environment. The tool building case is interpreted as a way to reflect on how design generation proceeds, bringing into clearer outline the understanding of design that has been in play during the making. The third artefact is a computer modelling software, where rapid exploration of tile-based form is made possible. The premises of the artefact arise from identifying tendencies and goals in the author's pen-and-paper sketching process. The program becomes interpreted as a way of explicating one puzzling element in the drawing process, again helping further reflection on that aspect, together with the insight collected through building the two previous artefacts. A drawing board is one arena where personal beliefs, rules and design idioms become played out. Different drawing methods, such as perspective methods, support a subtly different route to conjecturing about spaces and environments.

It is acknowledged that the building process is potentially very subjective, and the making of the design tools becomes consciously examined from the viewpoint of what could be called personal theory building, more properly the articulation of one's guiding design philosophy or a personal belief system. The tool artefacts also contribute to the development and better understanding of one's own development, which is then opened up and articulated in the text. The topics and outcomes are related to more general-theoretical concepts within design literature, which supplies the overall frame within which the practice-led research is situated. The starting point for dismantling and examining such a process is Donald Schön's idea of reflective practice, which integrates elements of more subjective know-how as a response to the situation. Here the focus is on Schön's conceptualisations and vocabulary that can be applied on skill development, such as repertoire building, reflection-in- and reflection-on-action and the notion of generative metaphor.

In this dissertation, it is argued that for the practice-led researcher, making one's own tools is centrally seen as a process where one's beliefs and understanding about design becomes conceptualized and challenged. The tools as material artefacts become solid entities for reflection, but also help anchor and guide the research project. The tools have been built first, and each time the challenge has been to interpret and explain what their making has achieved toward the research ends. This forms the central stimulus for reflective thinking for each of the cases. The three middle chapters conclude with this discussion and an interpretation of the work, and the final chapter collects together the whole journey, examined as a trajectory where the artefacts have both followed and depended on each other. The work done and the theoretical literature read permit to conclude on the whole experience, much as each artefact case is concluded individually.

The contribution of this research is a description of a way tool-building can be utilized as a means towards personal reflection and theory-building. It is suggested that tools as research artefacts should form an important domain within practice-led and research through design approaches. The tool building angle gives a handle into the researcher's design process itself, as the tools remain a trace of the beliefs, goals and decisions that guided their creation.

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Design Credo:
The making of design tools as a personal theory building process

Design tools, just like any design objects, can be examined from the angle of their making, and this viewpoint can be used for exploring designing itself. This thesis presents one way to build tools for reflecting on design approach and developing skills and

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