DESIGN OF DESIGN TOOLS: THE CREATION OF TOOLS AS A PART OF A PERSONAL THEORY-BUILDING PROCESS

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ABSTRACT

This paper is a first-hand account of creating one's own design tools in an art and design context. This practice-led research project investigates the intertwining of a design drawing process and the making of a software artefact for sketching spatial form out of tiles. This approach is compared with other practice-led research into design tools. The premises of the software, which emerge from design drawing, are explained as a part of the author's process of building a personal theory of space. These premises become materialized in the design tool artefact, which again in turn brings new elements to the design drawing process. A concept of generative strategy explains the way material design tools play an important part in core design activity, and not just as assisting devices. To complement the study, other designers and artists made outcomes with variants of the tool. These are examined to further dissect the tool and find evidence of the strategies in play. The overall outcome is a demonstration of one way a designer

can develop understanding of computer-based and material design tools in design activity.

INTRODUCTION: DESIGN TOOLS

This research seeks ways to approach computer-based tools from a more designer-led angle. The question is how designers could better build personal theory into tools and this way get more of the potential and variety that computer tools ought to offer.

The method is practice-led; the researching designer engages into design work, which is also a continuation of previous design activities. This work on design tools involves both engaging into traditional mediums and building new software tools. The context is the design of spaces and interiors. A design tool represents an idea or theory about space for the purpose of making proposals of spatial form.

Practice-led research has utilized creation of artworks (Mäkelä, 2003) and the exploration of specific material (Nimkulrat, 2009a) to produce knowledge in a research project. Design tools have also been studied by designing researchers, and the present research is positioned among work made in gestural design tools (Hummels, 2000) and the appropriation of existing software into creative mis-use strategies and hybrid processes (Sevaldson, 2005). This project adds to this growing body of knowledge of design tools emerging from design fields. Design tool as an artefact in a practice-led design research project is an angle that has been little explored.

Pen-and-paper perspective methods are used as an example of self created tools and knowledge created in the design field. The various drawing methods have been modified by designers to suit particular situations

and disseminated through manuals and education. Practice-led research on materials and tools is offered as a continuation of this process.

Design tools are used to work with forms and ideas independently from a specific material. The relation to drawings and models is also intimate and depends on personal beliefs. This paper examines design tools as a part of a personal theory-building process. As a theoretical framework, the paper revisits a concept of a *generative strategy,* a direction-establishing move in the early stages of design (Darke, 1984)(See also Lawson, 2006, 188-199).

TOOLS AS GENERATIVE STRATEGIES

Darke saw the choice of a primary generator as an important, decisive moment in a design process. Establishing the primary generator is a move which sets the stage for further moves, making it a core design decision. In this it is closely related to a guiding idea, or a first idea of design. (Darke, 1984.)

Many studies of design processes have a notion of a pre-existing schema that guides design and simplify real-world situations. Christopher Alexander already discussed the schema as part of designer's learned world view. He was worried of imaginary and overtly geometrical schemas he saw perpetuated at that time in design education. (Alexander, 1964.) Herbert Simon discussed different styles of design as emerging from what he modelled as a generator-test cycle of design. In his given example, it is significant for a design outcome if a house is designed from the outside in or from inside out. Stylistic consistency in different schools of design might then emerge from this kind of differences in approach. (Simon, 1975)(See also Simon, 1996, 128-130.) A conjecture-analysis model of design by Hillier et al. (1984) also suggested that designer works by proposing solutions first. The argumentative evaluation and the revision of the propositions can begin only when something tentative has been made.

Both traditional and computational design tools can be examined as a source of significant creative design moves and not only as task-oriented devices. The generative strategy is useful in making sense of design and artistic activity without a particular problem setting.

For clarity, the generative strategy should be separated from purely computational approaches, such as the intentional use of generative and genetic algorithms to produce form. The view here is that any making of a trace is intrinsically generative act, and the strategy is related to how these acts are chosen and collected together. In this way a generative strategy is likely to be present in all normal design processes.

The generative strategies are linked to what could be called personal design philosophies. This means that a designer or artist has a persistent belief system that guides the realisation of individual pieces over time. This overall artistic personality becomes the starting point for design outcome variations, and is also developed over time. Systems of harmonious proportions, classical orders of architecture or compositional rules are examples of *quasi-theoretical* (Hillier et al., 1984) ideas that have been developed, distributed and carried on, but are not a necessary part of a more general theory of design. An artistic credo and other personal belief systems work as bases for generative strategies and tool use. These are part of designers and artists repertoire (Schön, 1983, 138), from which tentative and partial outcomes can be drawn and tried on a situation.

Instead of dismissing the quasi-theory as undesirable, it is here promoted as an important part of developing a competence of design. This does not mean adopting outmoded ideas like the abovementioned classical orders, but a more appropriately scaled process of personal theory building and considerate tool use.

Originally, the concepts of the generative strategy and the primary generator were explanatory devices to show how designers reduce the "cognitive load" of a task. The concepts are here seen as useful without the link to cognitive explanations. The strategies are potential moves in the designers' or artists' palette of conceptual tools, without needing to ask what happens in the designers head. The tool as generative strategy does not just make things easier for the designer, but enables richer processes.

THE PRACTICE-LED METHOD

This research uses a practice-led approach. This means the research is based on a practical design project, the creation of design tools. Different design tool artefacts have been made, and the new things that are learned through that process are explained in text.

Donald Schön gave outline for defining practitioner knowledge (Schön, 1991). He could suggest a number of ways a practitioner, with an insider view to the practice, could engage in research more systematically. The building of a repertoire forms part of such research. A designer has a repertoire which is his or her whole past experience and knowledge at that point. (*ibid*, 138) Distributable knowledge can be built out from a retrospective analysis of these experiences.

The building and study of artefacts is an important aspect of this process. Ceramic artist Maarit Mäkelä's work (2003) focused on exhibited artistic productions, and textile artist Nimkulrat (2009a) has discussed research through artefacts (2009b), engaging into a process of working with paper material and the way it shapes the creation.

Biggs (2002) demonstrated how artefacts alone do not work as a research contribution, and offered a rationale for combining text and artefacts as a fully formed research outcome. A central element in research is dissemination of knowledge. Objects alone would be subjected to wide interpretations depending on the

context they are placed in. Presenting the objects alongside a context then completes the artefacts as distributable knowledge. The researcher creates new design artefacts but also has the responsibility to explain them in text so as to "give them voice". (Mäkelä, 2007.) As Mäkelä says, this can be facilitated by positioning the artefact into a suitable theoretical context.

In this research, the theoretical framework is built on the concept of the generative strategy as discussed above. This research has proceeded through making design tool artefacts, in part allowing these to lead the research project and the reading of theory. It has begun with exploratory design work, but has become more goal-oriented and analytical in later stages. The text is produced through looking back at the making of the tools and their underlying motives in light of the literature.

Perspective manuals are here offered as an example of a very visual artefact that is also accompanied by a complementing text. It would be difficult to explain the methods in just text, whereas the images alone would give misleading ideas about their purpose.

TOOLS AND PRACTITIONER KNOWLEDGE

Both material and computer tools intended for designers contain assumptions about what is practical and desirable for designers. The way software is interfaced shapes the understanding of the computer as a tool. (Manovich, 2002, 62) Similarly, drawing on paper is not neutral and has complex ties to the ways environments become built (Evans, 2000). Therefore each software program or a drawing method represents an idea about what is useful for design. In this way they are theory-like objects.
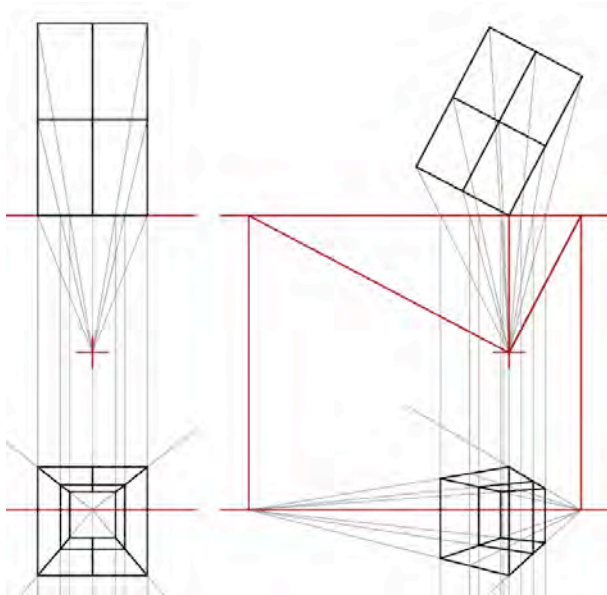

Figure 1: A perspective method converts the known dimensions of an objet into a perspective view. The image is based on John Pile's (1985) simplified method intended for interior designers.

A rigid perspective method is used to transform a defined, already existing model into a perspective view of that model (Figure 1). At the other extreme it is possible to draw a quick sketch starting with a vanishing point. The outcome is based loosely on the idea of perspective without a previously existing model (Figure 2). The vanishing point is then not an auxiliary device, but the generative seed of the drawing.

This is reminiscent of how Paul Klee took a line "out for a walk", aimlessly wandering for its own sake. (Klee 1961, 105) To Klee the lines are not just aesthetic possibilities on a canvas but contain generative potentials. Klee's perspectives (*ibid*, 140-145) are a result of lines playing each other on a surface instead of converting existing volumes into views. The vanishing point is not always even drawn but remains an idea.

Between these extremes, drawing on paper then offers large palette of choices for the designer. The rules that govern the drawing and also the drawing itself are made of the same "stuff", lines on paper. The freedom is in being able to set the rules to limit ones freedom. The skilled sketcher can switch between different rules on a whim.
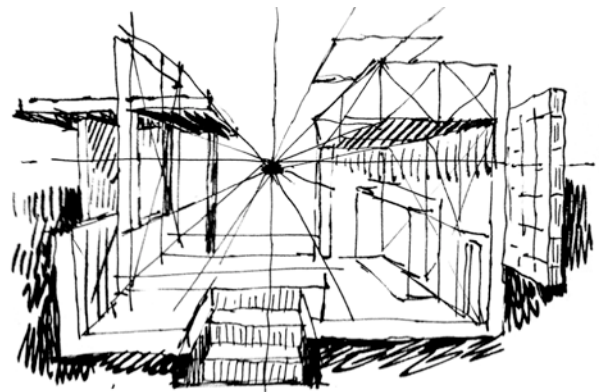

Figure 2: A spatial proposal sketch based on a vanishing point. The vanishing point acts as the generative seed of the drawing, and not just as an auxiliary device.

The sketching example shows how a vanishing point may be a starting point for generating spatial outcomes. Why it makes sense to call this a strategy is that actions stem from the choice of the approach, but the ensuing process is not chained to it. Instead, the drawing begins to accumulate organically from the first choice, much like Simon's hypothetical outcome of a house designed from inside-out as opposed to outside-in.

The perspective drawing both as a rigid method and a style of sketching is design knowledge originating from the practitioners themselves. Influential perspective manuals such as Jay Doblin's perspective (1956) and William Kirby Lockard's Design drawing (1970) stress that the rigid perspective drawing method should be seen as a stepping stone in learning to draw views directly in free hand sketching. Particularly Lockard promotes the idea that perspective drawings ought to be a direct way to work on design ideas. It is at this point

perspective drawing would become really a generative design tool and not just a mechanical device.

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 represent a practitioner-originated knowledge, part of a repertoire-building process much in the way that Schön suggested (Schön 1991, 315). Not simply a how-to explaining a procedure, the books contain opinion drawn from long experience, of how the designer could and should draw. This knowledge is transmitted by both images and text.

HAND AND THE EYE: COMPUTER-BASED TOOLS

The designer, just as she adopts an underlying theory in using perspective method on paper, also adopts the underlying assumptions in computer software. Apart from offering practically useful tools, building design tools into interactive software has good potential for distributing ideas about how to design. However, standard modelling software is not as flexible for changes as the perspective method on paper. The software medium also limits the ways a non-programmer can contribute and add to this knowledge, unlike in the age of paper-and-pen methods. Practice-led research into design tools is a way to go forward in identifying the ways designers would like to build their tools.

The present work is here positioned among two design thesis research projects on computer-based design tools, both emerging from a design field. Neither produced design tool artefacts directly as concrete outcomes.

Hummels (2000) emphasises tangible, bodily aspects of gestures as the primal acts of form generation in a social design context. She is concerned that there is lacking dynamism in design representations such as drawings. Bodily gestures are instead intrinsically based on motion. Designers' inability to draw can limit what can be proposed through sketching. Object shape can be suggested by a gesture of hand. Sculpting is close to the body and therefore contains the potential for capturing time-based dynamism, but computers tend to muddle the elegance of sculpting behind clumsy interfaces. If the subtlety and precision of computer drawing and sculpting could be improved, it would result in better computer tools.

Sevaldson (2005) considers the active eye of the designer as an important aspect of generative digital design techniques. The keen eye of the designer picks up what is interesting from a chaos of on-screen material. Any software that produces rich enough visual material can be appropriated by the designer, not just dedicated design software. The designer adjusts parameters and combines things, and the literal tool-building through programming is not important in this approach. The more general description of design tool re-use and mis-use strategy can serve a basis for many different personal design philosophies.

Sevaldson concludes his study noting that hybrid processes (*ibid*, 317) seem to hold most promise for creative computer use. Parallel use of traditional and digital media is one simple example of a hybrid process. His hybrid processes are fairly large scale; the continuation of this idea here is to describe one hybrid approach towards design tools as a part of a personal development process.

Both Hummels and Sevaldson convincingly cover their respective directions. Hummels' starting point was to interpret bodily gestures, whereas Sevaldson's approach seems to favour the eye and the artistic designer as a seeker of kind of digital "found objects". The directions differ due to the personal interests, beliefs and accumulated experience of the authors. They are rooted in design practice and driven by a strong artistic credo. Yet such projects are never so subjective that they would cease to be useful to others. Designers can use them as bases rather than apply them directly. As the accumulation of insider accounts grows it also helps generalise about tools.
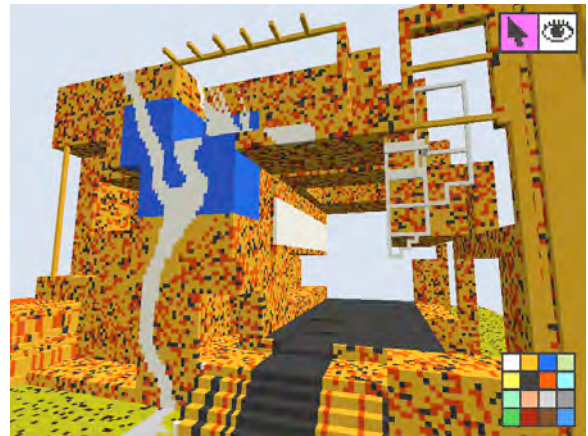

Figure 3: The matrix sandbox. The software allows shapes made out of differently coloured tiles. This example uses the more full spectrum of options available to the author.

The tools closer to bodily gestures are more intuitive and allow development of practical skill. There is no reason why this could not be built into design tools. Sevaldson's insights about visual thinking and "mis-use" should be appreciated. The outcome made with software is not a utilitarian object but matter for further inspiration.

Skilled drawing to me seems still to combine the best of both worlds. The power of drawing resides in the way it allows diverse ways for ad-hoc self-building of rules and tools. Even a simple drawing is an act of generation, and the active eye can do its work there too. I attempt to transfer qualities of drawing into a computer software and look at the results critically.

CASE: THE TILE SANDBOX TOOL

This software tool (Figure 3) was built as an extension of a sketching process. The software was written during

years 2008-2010, using C programming language and OpenGL graphics library.

The software offers a perspective view into an environment made out of little tiles. A ground of 255x255 tiles is given as a starting point. The full extent of the modelling space is 255x255x128 tiles, which can only be altered by modifying the program itself. The first person view is navigated with a combination of mouse and keyboard commands. Tiles can be selected and grown into six different directions (Figure 4). The tiles may be removed using similar commands, or they can be coloured using a fixed palette of sixteen colours.

Lack of contextualizing in software products makes them difficult to appreciate as design knowledge. Technical research often presents advancements in prototypes without much explanation of the creative motives behind them. Therefore I relate my processes to existing practitioner accounts in art and design context and not individual software tools as such.

It still can be noted that the interaction design has been influenced by the conventions in popular first-person video games, played with a combination of mouse and keyboard. Smoothness and fluidity of experience is also a video game quality I wished to achieve. This means that the view angle can be changed at the same time as the model is modified, if the person is able to manage both at the same time. The benchmark for intuitively simple modelling was Google Sketchup, but the component-based approach was to be avoided as not very drawing-like.
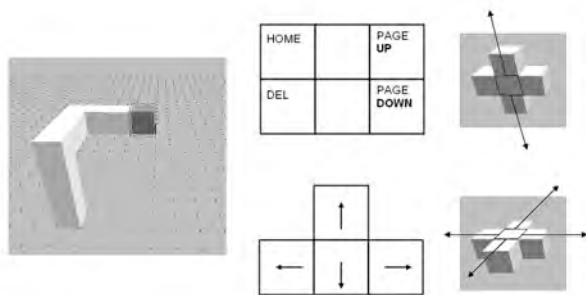
Figure 4: The basic interaction design of the software. A standard keyboard layout corresponds with movement of a cursor in space. (Left) A single key press moves the selected tile. All additions are incremental just as in drawing a line on paper.

BACKGROUND IN SKETCHING

In the following, the motivation for the design of the software is described in terms of identifying goals in my process of sketching space.

The most general goal for the software development was to bring together something of the flexibility of drawing to the modelling of spaces. This is a continuation of my personal process of drawing design sketches, which involves learning to draw spaces and environments (Figure 5).
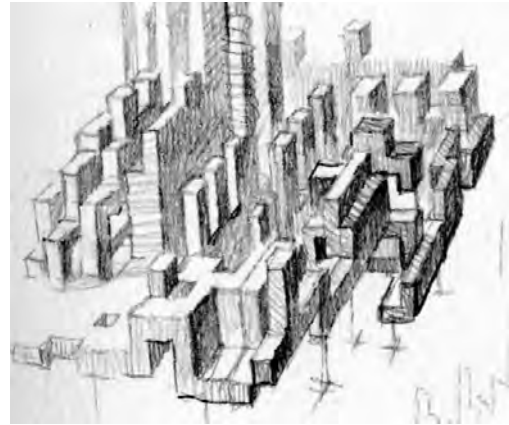

Figure 5: From author's sketchbook, 2004. The image shows initial interest in the use of numerous cubes as an organisation. This one-off example is very sculptural.

The sketches are a way of proposing or conjecturing about what could be. The talk-back of the sketch during drawing produces new ideas about the design, making it one possible medium for reflection-in-action, a virtual world. (Schön, 1983, 157.)

The spatial design context means the views are meant to convey space from an experiential angle, and not for example for solving structural or material questions. These are left as the more implicit content of the drawings.
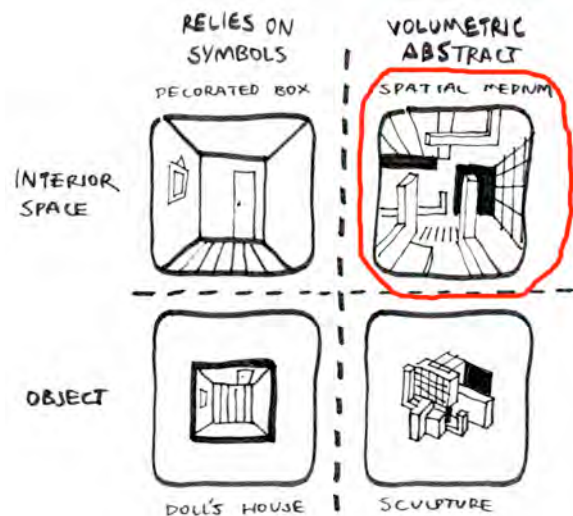

Figure 6: A map of tendencies in the author's sketching process and the development of a personal understanding of space. The desired goal was to achieve a volumetric, abstract understanding of space understood as interior, experienced space. (Top right corner)

The personal goal can be positioned along with some of the kind of drawings I have wished to avoid. The map of tendencies in my sketching is collected in Figure 6. The top left corner depicts a room in perspective, but the picture is not very spatial. It is a combination of symbolic depth and scale cues. In this way interiority can be suggested through the use of signs, but in the identified personal goal this would not be a satisfactory design tool.

There is nothing wrong in depicting space from the outside, as for example with axonometric perspective (Figure 6, bottom right corner). To concentrate on interior space I wanted to draw space "from the inside" as it might appear to a person traversing in it.

Showing the inside of a room does not always guarantee spatiality. The outcome might still seem like an object than a serial, continuous space. A doll house type picture is an example of this (Figure 6, bottom left). The symbolic way of presenting outside or inside in an image is very useful in illustration and painting art, but for personal purposes this effect was not desirable in the design drawings.

The goal of the learning process can now be retrospectively identified (Figure 6, top right corner). My intention was to be able to exercise ability in drawing space as an abstract, serial, homogeneous substance from an experiential view.

At an earlier point, the different goals were identified as shortcomings or mannerism that needed to be overcome. But in retrospection, all the goals appear as possibilities within a map, a toolbox of various directions. They are generative bases that can be summoned at will at various stages of even a single design sketch.
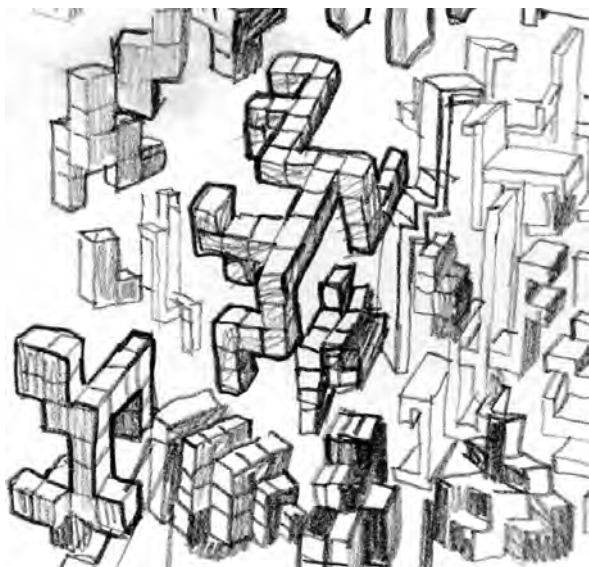
Figure 7: From author's sketchbook, early 2008. The making of the software begins to influence the sketching process consistently.

These aims are not presented as something all designers should strive for. Any other designer might choose precisely the opposite goals for his or her drawings, such as scenarios and person interactions.

BUILDING THE GOALS INTO SOFTWARE
The development of the software artefact was instrumental in addressing the goals in the sketching process. The intense interest into the software necessitated also drawing and sketching out desirable outcomes for the software (Figure 7).

Inclusion of these features was intended to assist in meeting the goals in the software:

- Additive and subtractive approaches are given equal weight. It should be just as easy to add and remove form.
- Rapid incremental modelling is meant to resemble drawing at least to some degree. Components, such as geometries and real material parts are avoided.
- Inside and outside views are neither favoured. It should be as easy to model form from inside as from the outside.
- The experiential view would facilitate a design approach towards interiors. Architectural and drafting conventions are avoided.
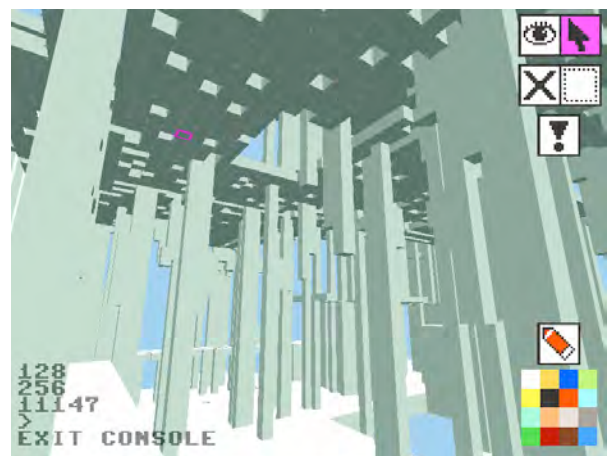

Figure 8: Semi-random shapes made with the program. Outcomes such as this in turn informed the later sketching process.

WORKING WITH OTHER DESIGNERS
Outcome models were collected from modelling sessions where others could also try out the software. The outcome material was complemented by the comments and notes made by the designers themselves. This completes the project of creating a design tool by making it available to other designers. This material is meant to deepen the understanding about design tool artefacts.
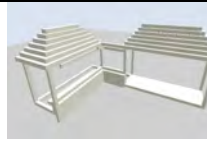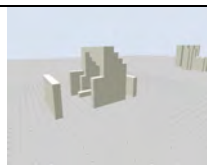
A modelling situation was arranged with design students enrolled in a master degree program in interior and furniture design and industrial design. At this first stage, few design researchers were included, still fresh in the doctoral program with background in design work. In this way the participants were not far in design experience to the author. It was meant that the situations were more like a designer showing a design tool to another designer, rather than a data collection session or a user study. In the first set the designers were given a task of building a snow fortress, with some 20-30 minutes maximum of time to produce it. In this stage, the on-screen activity was recorded with a video camera. They were assisted in using the program functions.

As the study focused on the choice of the generative strategy, it was not desirable to complicate the setting with long design processes. Therefore the outcomes represent design doodles and design sketches.

Another set of sessions took place later, and this time the outcomes were collected remotely. The participants were now more exclusively MA design students. A built-in logging was used to record the processes, and the logs were collected by e-mail. The logs were digital and small compared to video files and needed no setting up from the participants. Some changes were made to the program to facilitate easier camera views, to allow a more conventional way of rotating around central object. The program was supplied with a set of written instructions. All this aimed at removing the presence of the researcher, so people could concentrate on the task in the privacy own their chosen environment. The participants did the task themselves first, then sent the software and the task to another suitable person. In this way more material could be gathered, although this also resulted in some poorly documented material that had to be excluded from the study.

Overall, 24 unique authors provided works for all the tasks, some making more than one model. Participants were under 30, both male (11) and female (13).

Table 1: Outcomes from use of incremental version. First stage snow fortress task.
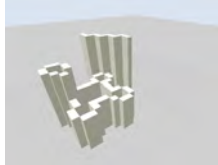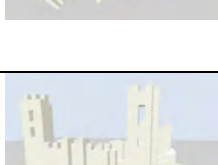
Tag	Thumbnail	Strategy interpretation:
I1		The idea of a narrative of a snow ball fight was realized by two shapes that fulfil the protective function in snow fight
I2		The fortress theme influenced the choice of subject matter, a recreation of oriental fort typology. (unfinished)
I3		The shapes fulfil the protective function in a snow fight.
I4		Accidental shapes were accepted as interior with slight modifications. "Igloo" feature on roof satisfies the outcome as a snow fort.
I5		Symbolic house was chosen as starting point. The tool was used to build up the model one wall at a time.

In both collections, two software versions were used that allowed slightly different ways of manipulating the modelling matter. The tile modelling medium was the same, only the available functions were different. This was made to see if changing the software even slightly would produce different results in respect to the designers' chosen generative strategies. The outcomes were inspected for evidence of different generative strategies towards a given task and the influence of the tile modelling in choosing the strategy.

VERSION A: SINGLE CURSOR INCREMENTAL (I)

The incremental variant (Tagged with "I" in the tables) uses a single moving cursor for all shape creation. This means only one tile can be selected at all times. The cursor is moved by using six movement keys, somewhat like the cursor in a word processor. As the cursor moves it leaves a trace of solid material behind it. A long, tall wall has to be built by moving the cursor through all the required positions. Existing tiles can be removed by selecting tiles one by one and pressing the delete key after each selection.

Table 2: Outcomes from use of paint selection version. First stage snow fortress task

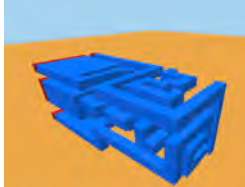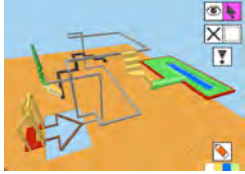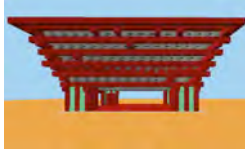| Tag	Thumbnail	Strategy interpretation:
PS1		The tool suggested that as a 3d pixel tool it could be used to recreate organic form, an igloo.
PS2		The extrusion tool was used to quickly satisfy the task with an iconic fortress plan shape. A person would fit to use the structure as defensive structure.
PS3		The student displaced the snow fortress idea to a metaphor, making a snowflake shape plan through extrusion. Unfinished, ambiguous scale.
PS4		The extrusion was used extensively to create parts of this fortress, one tower at time. Details such as arrow slits were carved in.

VERSION B: PAINT SELECTION (PS)

The other variant allows the designer 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. Then the whole selection leaves a trace. A wall can be created by selecting a row of tiles and then raising the tiles upwards until the desired

height. It is still possible to use only a single tile as a cursor.

LOOKING AT THE OUTCOMES

The first stage outcomes are collected into table 1 and 2. The second stage resulted in more outcomes, but some of these turned out to have less new approaches compared to the earlier stage. Only the more sophisticated second stage outcomes are collected to table 3. The tables contain thumbnail images and a short interpretation of the chosen strategy.

Table 3: Second stage open modelling task outcomes. These were made with both paint selection (PS) and incremental (I) version.

Tag	Thumbnail	Strategy interpretation:
PS20		Building footprints were drawn and then extruded to height. Balconies were also extruded. Was used like a conventional modeller.
PS21		Single cursor was used to make snake form, even though this was the paint version of the software. Tile properties were the origin of the aesthetic style of the object.
I22		Motion of cursor suggested motion as basis of the model. An association to TV contest maze then inspired to do the model.
I23		Existing building was copied through detailed modelling. The choice of model was suggested by the tile properties.
I24		The tile properties suggested a connection to a type of oriental ornamentation, which was executed through detailed modelling work.

THE MODELLING TECHNIQUES

The models and processes of making were examined for the presence of different building techniques and the generative strategies. The building technique was important as the chosen technique could be a potential creative strategy.

Using the incremental version, the subjects were practically forced into making a "snake" type continuous form. Even then, this would result in different approaches. Some (I2, I4) would first build a two- or three-dimensional outer frame of the whole object, which was then filled afterwards. Others (I5) would accumulate one wall element and then proceed to the next, without creating an overall frame first. These crudely correspond to the way a pen-and-paper sketcher can rapidly produce shapes in different ways.

Figure 9: Making the interior of model I4, a partial accident resulting from the work made from outside.

Unlike the incremental version, the paint select version allowed the designers to select and extrude larger shapes. This would often influence the choice of technique. The users of the paint selection version would draw a footprint of a building and then raise it to a height, like they had learned to do in common modelling software. (PS2, PS3, PS4, PS20)
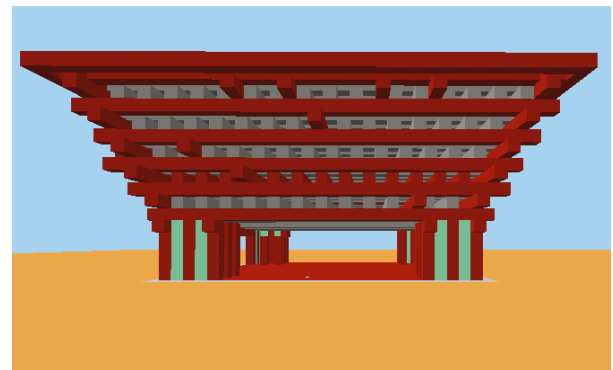

Figure 10: The Chinese expo 2010 pavilion shape recreated by a Chinese architecture student, using the incremental version.

THE GENERATIVE STRATEGIES IN PLAY

The dual role of the design strategy is a device to both help make the task more manageable, and set the stage for a creative outcome. It was apparent that some designers would try to get away from the task when they discovered an effective means to complete it (PS2). In the context of this study this is was not undesirable, and the time constraint certainly gave a motivation to do so.

The interpretation of the given task was one source of ideas. The task of snow fortress provided different

starting points for the designers, interpreted as a protective function (I1, I3) or an iconic fortress (PS4, PS2). One outcome was a metaphoric snow flake form. (PS3) The second task set was made more open, the designers would have to decide what to do.
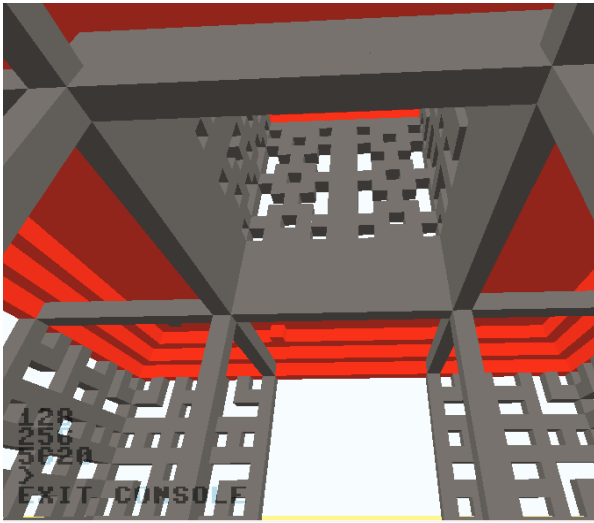

Figure 11: An interior with oriental influence. (I24)

Some designers accepted the tool properties as a starting point for their own ideas (PS21), whereas others would work on an idea that was already quite fixed when they began. (The Igloo in PS1) 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 strategy point of view, as the object to be modelled was chosen on the basis of the person's perception of what the program could do. An igloo and a Halloween pumpkin were chosen as a suitable object because the program was perceived to be able to handle free form.
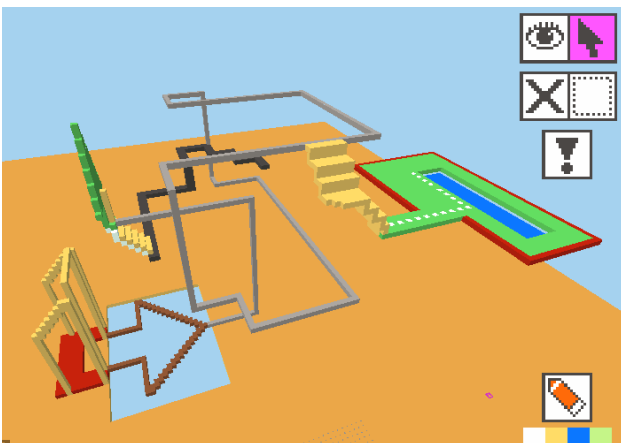

Figure 12: A three-dimensional maze influenced by the idea of a television game show. The incremental cursor was used as a snake that suggests form and directions as it goes along. (I22)

One chose to model an approximation of the China Pavilion in Expo 2010 (Figure 10), due to the apparent block-like visual identity of the original work. In fact, an oriental influence crept into a few of the works. In two cases (I2, I23) it also coincided with the designers'

cultural background, whereas one Finnish person also made oriental decorations suggested by the tile material (I24 in table 3, see also Figure 11).

Perhaps the most intriguing outcome was a model based on an idea of a television show where contestants have to negotiate a three dimensional maze. Here parts and three-dimensional paths float in space, ignoring laws of physics (Figure 12). This was suggested by the way the cursor snakes around the space three-dimensionally. The moving cursor of the tool suggested a theme strongly related to movement. Although the tool was used by many in a pen-like manner, in this outcome it is most apparent. Symbolic images and abstract paths are positioned with each other.

DISCUSSION

The longer process of this research was based on identifying personal goals in a design drawing process and building these goals into computer software. This stimulated self-reflection on the personal theory of space. The different mediums informed the development of each other (Figure 13). The first-hand nature of this project is a condensed version of a process that otherwise could be difficult to capture, justifying the practice-led approach.

This is one way to use hybrid ways of design tools, between the tangible realm of drawings and models and the possibilities of computational design tools. Drawing of cubic sketches was informed by the rapid way the computer can produce such forms. Identifying the cubes as a generative strategy allowed me to see an underlying "computational" quality in also the paper-and-pen drawing process. Preserving this aspect of drawing, without actually making a pencil drawing program, was successful to the personal project but also had an effect on others' use of the tool.
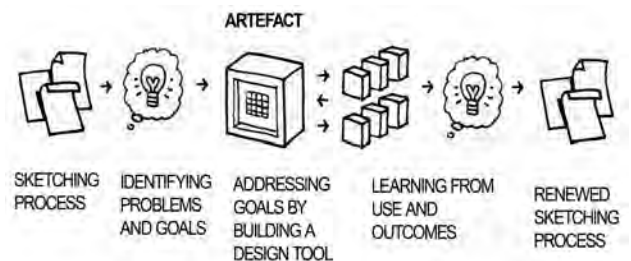

Figure 13: The phases in the process. The actual design tool artefact is marked.

The potential for a generative strategy in the software is completed by each designer's own. The idea of tiles as a more general basis for a drawing-like process appears validated by the variety of techniques it enabled the designers to choose from. The students also chose other angles than the one favoured by the author, for example drawing symbols and iconic models. Very few used it to design "from the inside". The convention of modelling space from the outside is quite strong and has also reasons. The software could have been made to push the

designers more to attempt this to give more material for inspecting this angle.

Engaging into a creation of design tools is a way to sharpen focus and understanding into one's own design processes and the tools itself. Building aspects of personal theory into a tool form is a way to incorporate ideas about how to and what is design in a material or digital form. The materials and tools of design, interpreted as generative strategies, are important part of practitioner knowledge. Design tools are also a way of distributing the ideas to others, either with or without a complementing text. They become building blocks for personal theories and strategies.

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