3D VIRTUALITY SKETCHING:
INTERACTIVE 3D SKETCHING BASED ON REAL MODELS
IN A VIRTUAL SCENE

ABSTRACT

Sketches and working models are without doubt one of the most widely used tools in the architect’s repertoire. In the early phases of the design process in particular, they represent an essential part of the exploration process. For the most part, however, sketching and model building are separate and sequential steps. This paper examines how both media can be linked to each other more effectively so that the design process is more continuous and the transition between the two media more fluid. Using a multitouch table with additional 3D real-time object recognition, a prototypical system was developed and realized as part of a research project in which an interactive 3D sketching tool was linked with a real 3D working model.

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1 INTRODUCTION

In an interdisciplinary project we examined new approaches for using computer and information technology in the early creative phases of the design process. The aim is to develop digital tools that strengthen rather than hinder the design process so that a continuous workflow results, in accordance with the motto “the simpler the tool is to use, the less it gets in the way of the actual process of designing.” As a result, established design tools are not entirely replaced by digital methods but instead are combined with a view to making the most of both worlds: by combining the advantages of each realm, we expand the possibilities of designing in real and virtual environments.

Building on the pre-existing Collaborative Design Platform (CDP; Ochabek et al. 2011a, 2011b), we examined aspects of human-computer interaction and the use of computers in the early design phases.

The subproject described in this paper is a 3D sketching tool for the early architectural design phases that makes it possible to annotate, extend, and label real working models in a virtual environment in real time. We examine how linking together established design tools—the sketch and the working model—can contribute to supporting a continuous design process and what advantages this may have for the designer.

2 DESIGN TOOLS

Imagining future situations has been a fundamental part of the work of an architect since the end of the Renaissance. As building projects became ever larger and more complex, it became necessary to find methods for visualizing the building process and to verify its design and construction in advance: “The whole point of having the process of design separated from the process of making is that proposals for new artefacts can be checked before they are put into production.” (Cross 2008; Busston 2007). Or as Fish and Scrivener describe it: “The use of words, pictures or models to stand for objects, scenes or events not physically present enormously increases the mind’s ability to visualise” (Fish and Scrivener 1990).

Over the years as culture progressed, different tools have been used to support the design process. Surprisingly, despite the widespread use of computers in architectural practice, computers have not become an established tool in the early design phases. Working models and freehand sketches, on the other hand, remain fundamental design tools at the beginning of the design process. Depending on the design brief and the specific design problem, architects use one or the other as a tool to assist thinking. Numerous academic papers and books have examined the topic of design tools, creativity and finding ideas, as well as what characterizes design tools and processes and the findings can be broadly summarized as follows: design tools are used to represent and to test one’s own ideas; they help designers to create an internalized image of their thoughts—that is, they render designers’ thoughts visible and accordingly support the creative process of designing. The architect “holds a conversation with the drawing,” as Schön describes it (Schön 1993). The process of drawing helps engage in what Schön calls “the reflection in action process.” That is, architects frame the problem in order to come up with an idea. They try to understand and to define the problem. Secondly, they draw the idea. While drawing the idea the architect simultaneously reflects on the idea, evaluating its consequences and implications, a process that can lead to a new or refined idea. The process then repeats. This process, which has also been termed “visual thinking,” is a key characteristic of the architectural design process (Anheim 1971).

In response to the above, the freehand sketch and working model have become standard tools. If one takes a closer look at each of these tools, one can note the following characteristics:

Table 1: Comparison of freehand sketch and model

<table>
<thead>
<tr>
<th>Freehand Sketch</th>
<th>Working Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D</td>
<td>3D</td>
</tr>
<tr>
<td>Quick and flexible</td>
<td>Better spatial impressions</td>
</tr>
<tr>
<td>Can represent any scale</td>
<td>Can be explored and revisited with both hands</td>
</tr>
<tr>
<td>Tactile feedback</td>
<td></td>
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</tbody>
</table>

The differences noted here are actually qualities that speak for one or the other tool, and if one looks closely it is apparent that they hardly relate to one another. Although both tools are used in the design process, they are rarely used in combination. As a result, switching between the different media interrupts the design process and creative workflow. This research project takes this as its starting point and examines the possibilities offered by linking the sketch to the working model in the help of computer technology. The aim of this project is to connect existing and established design tools with a view to optimizing the use and advantages of both.

3 THE IDEA

Freehand sketching is a design method that has been widely used for hundreds of years, and more so than perhaps any other method. Its popularity is, of course, not coincidental but rather reflects its special qualities. Fish and Scrivener list four important attributes of sketches (Fish and Scrivener 1990). Of particular interest are the ability to depict abstractions at different levels (Cross 2008), to embody intermediaries (Busston 2007), and with it the ability to anticipate those among the most fundamental attributes of a freehand sketch. But why is this?

In the early design phases, the information available is often vague and incomplete. The ideas that float around in the designer’s mind are not yet well formed. A design tool needs to be able to accommodate these kinds of imprecise thoughts and vague information. This is essential for a dialogue between the designer and the drawing to arise, which in turn serves as a basis for refining and developing the idea.

Closely related to this is the concept of emergence. The term emergence describes the process of making qualities and things visible that cannot be explicitly formulated or depicted (Simon, Diakos, and Tan 1995). In the context of designing, this is essential as it helps designers to perceive something in a drawing that may not be what they originally drew. The sketch as a design tool and its capacity to accommodate emergence represents a catalyst for stimulating not yet conceived interpretations of an idea. In other words, the sketch provides an opportunity for something new to emerge from the process of drawing. To begin with, a site plan of the competition site and surroundings can be seen on the table. An architect is tasked with developing a design for an urban environment. Rather than working on-screen with a mouse and keyboard, he or she uses a large multitouch table equipped with real-time object recognition that will “see” the objects in the model. To begin with, a site plan of the competition site and surroundings can be seen on the table. The architect begins by cutting blocks to size out of a material of his or her choice for use with the model—can contribute to supporting a continuous design process and what advantages this may have for the designer.

4 USER SCENARIO: AN URBAN DESIGN COMPETITION

An architect is tasked with developing a design for an urban environment. Rather than working on-screen with a mouse and keyboard, he or she uses a large multitouch table equipped with real-time object recognition that will “see” the objects in the model. To begin with, a site plan of the competition site and surroundings can be seen on the table. The architect begins by cutting blocks to size out of a material of his or her choice for use with the model so that the positioning of approximate building volumes can be tested. After some experimentation, the architect settles on a first potential solution. The next step is to examine how the vertical articulation of the blocks and facade design will influence the design. The architect places a SpaceMouset with a camera symbol on the multitouch table, and an “ego perspective” of the design idea appears on a touch-screen arranged next to the model (3Dmouse). He or she positions the

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After a while, the architect asks a colleague for input on the design as it stands. The colleague has a few ideas and shifts some of the blocks in the real 3D model on the multitouch table. The perspective view on the screen updates accordingly to correspond to the new arrangement of the real model. Because the facade designs have been intelligently mapped to the building surfaces in the virtual model, they shift along with the blocks.

To show his or her idea more clearly, the colleague shifts and tilts the SpaceMouse to adjust the view on-screen with comments, arrows, text, and hatching. The two colleagues continue to refine and improve their idea, discussing alternate meanings of facade articulation and urban constellations.

6 THE SKETCH TOOL

The project shown here builds on work done last year on a developed design environment for urban planning at a scale of 1:500. By directly coupling a real, volumetric model (a working model as traditionally used for urban design projects) with interactive digital content, the gap between the real model and interactive content is bridged, separating the information that is stored with the otherwise purely physical model (Schubert et al. 2011a, 2011b). The technical basis for the design platform is a large-format multitouch table. Coupled with real-time 3D object recognition, the table acts as a “sizable interface” that, in addition to reacting to touches and markers, can sense objects on the table. The 3D data from the model on the multitouch table can serve as the basis for simulations, analyses, and rough calculations. The designer is equipped with an additional information layer containing simulation data and analyses that are displayed directly on the model and help him or her evaluate the consequences of design decisions. The physical model and the computer, previously two separate realms, are now united, resulting in a continuous design process without interruptions when switching between media.

This basis has been extended in this subproject to include an interactive drawing tool. In this situation, the multitouch table functions as the input device for the real, volumetric model. A separate touch screen is set up parallel to this. The scene on the table (consisting of GIS data structure and the 3D data of the scanned real model, as well as supplementary simulation data) is displayed on a real-time perspective view on the touch screen. The direct and synchronous connection between the model environment and the touch screen makes it possible to interactively connect both tools. The designer works with the working model on the table. Further options can be added in real time on the additional touch screen using a pen applied to a perspective view of the design scenario. The user can draw on and in the design scenario, annotating and interacting.

6.1 Paper Mode / 2D

This function is in a manner similar to tracing paper: a semitransparent layer is laid across the entire scene onto which one can draw and sketch without having to adhere to any particular geometry. As such this mode is very similar to the traditional method of using tracing paper with a drawing beneath it. The sketch and the relationship to the 3D scene are dependent on the viewing position and are always parallel to the front face of the camera. A mapping function can be used to “lace” the drawing onto the texture of the 3D volumes.

6.2 Object Mode / 3D

In Object Mode, individual objects, buildings, and surfaces are recognized, independent of whether they derive from the real working model or from the underlying GIS data of the surrounding buildings. This makes it possible to draw directly onto individual objects and buildings in the model. For this, the drawing is composed into a vectorial texture, referenced in 3D space, and displayed on the respective surface in the scene. In other words, the sketch is mapped to the envelope of a building and makes it possible to draw in perspective onto the scene shown on the screen. The relationship to
In addition to the purely 2D and 2½D modes, a 3D mode has also been implemented. Using the existing 3D data as its reference and environment, this drawing mode makes it possible to create 3D mesh models. Three-dimensional structures can be drawn in two dimensions and then automatically converted into 3D objects that sit within the existing 3D structure of the model.

7 USER INTERFACES (UI) FOR CREATIVE PROCESSES

Based on the findings of several researchers working on creativity research in human-computer interaction, we describe how user interfaces can enhance creative processes (Shneiderman 2000; Resnick et al. 2005; Terry and Mynatt 2002). Resnick et al. have found design principles for tools to support creative thinking. Terry and Mynatt also recognize creative needs in user interface design and provide guidelines for UIs used in creative work. Their main focus is on the creation and evaluation of an idea. Based on their findings, we identified the following important requirements for the user interface in our architectural context.

7.1 Provide the Ability to Sketch

Hand-drawn sketches and diagrams are essential tools for architects’ creative reflection (Resnick et al. 2005), and we therefore provide a sketching tool. As we have seen in section 3, the visual appearance of a sketch plays a central role in the ideation phase, and the creativity tool should not change its nature. The original sketch is preserved along with all its inaccuracies, irregularities, and wobbly lines that may serve as a spark of illumination in the ideation stage, when a new idea arises. The sketchy, unpolished appearance has a further advantage in that it does not give the impression of being complete. There is no illusion that a lot of effort has been given to carefully elaborating the

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idea. Purcell and Gero call this phase design fixation (Purcell and Gero 1998). The presentation of an idea in a form that is too polished hinders the creation of new ideas and fosters premature fixation on a certain idea.

7.2 Cycles of Ideation and Evaluation—Exploration of Alternatives

The generation of large amounts of ideas that are constantly being evaluated is a characteristic of the creative process cited by many researchers (Shneiderman 2000; Resnick et al. 2005; Robertson and Radcliffe 2009). Terry and Myatt examine the exploration of alternatives and their evaluation in detail (Terry and Myatt 2002) and note that "interfaces should offer a dedicated space in which to perform near-term experiments, without needing to modify the document or its data. This capability is sometimes called a 'what-if' tool."

Many user interfaces, however, force the user to progress linearly through a task where each step replaces the current state with a new state (Terry and Myatt 2002). In the paper mode of our 3D virtual sketching tool (see section 6), we have avoided this additional burden to the user and do not require the user to explicitly create copies of their data to create multiple versions. In this mode it is possible to generate variations sequentially (one after the other) or in parallel (multiple ideas at the same time). A new, "sheet" of paper is simply added to the scene by dragging one out, while the previous version is shown in miniature on-screen. Multiple miniature views of the same scene are visible at the same time. By clicking on one of the miniatures the user can return to an earlier variant. Variants can also be deleted at any time. Once the user is satisfied with a sketch, he or she can incorporate it by "baking" it into the scene. The sketch becomes an integral part of the 3D scene and is always shown with further new variations.

7.3 The Influence of the User Interface on the Idea

Roberson and Radcliffe describe the ways in which a CAD tool can influence the design problem when used to solve creative problems (Roberson and Radcliffe 2009). Software limitations, in particular, along with bugs, can cause significant disruption during the problem-solving process. The creative solution can also be influenced by the designer's proficiency with a given tool. Time pressure may result in generating ideas that are easy to make with a particular tool. Ideas that may be more suitable but are more difficult to make may not be investigated. Conversely, when a designer is particularly proficient with a tool, it can also result in the production of sophisticated but sometimes unnecessarily complex solutions.

Resnick et al. argue that a creative user interface should have a "low threshold" for beginners, but also a "high ceiling" for experts to create outstanding projects (Resnick et al. 2005). In addition, interfaces should offer "wide walls" in order to be able to explore a wide range of different ideas.

In order to create a system with maximum freedom for the user, the interaction needs to be intuitive and simple. Users draw directly in 3D on the multitouch screen as they would do with pen and paper (see section 6), a simple and intuitive means of interaction with the tool.

7.4 Support, Collaboration, and Discussion

A large part of the architectural design process is accompanied and propelled by communication between members of the design team and between the design team and their clients, the building’s users, or other participants (Lawson and Lake 1997). Small group meetings with rapid sketching and discussion are particularly effective (Roberson and Radcliffe 2009). Ideas can be reviewed collaboratively, and new ideas may arise as a product of the diverse backgrounds of the group’s members. A CAD tool on a normal personal computer is not conducive to this process. Aside from the software limitations, people cannot work collaboratively standing in a crowd around the operator.

Our setup consists of a multitouch table and a touch screen, which fosters collaborative work by enabling several participants to work at the same time on the same scenario. Currently, multiple people can work with the physical model on the multitouch table or change the camera view, while at the same time up to two people can work on the touch screen. The number of touch screen operators could be extended if the hardware were able to detect more than two touch points simultaneously. Additionally, it would be possible to collaborate remotely, because the scenario and the sketches are digitally transferable.

8 CONCLUSION

The concept shown in this paper describes an interactive sketching environment based on a real volumetric model and combines established design tools in a new and intuitive way. The direct coupling of a physical working model with an interactive 3D sketch tool opens up totally new ways of approaching architectural design problems. Taking into account ergonomics aspects and the patterns and workflow of architectural design problems, an interactive 3D sketch environment was developed and realized in prototypical form. The resulting system overcomes many of the interruptions caused by switching from model to sketch to computer visualization, creating the conditions for a continuous design workflow. In addition, the ability to sketch over other sketches or to sketch inside other sketches provides immediate distortion-free feedback and facilitates the process of visual thinking in a completely new way.

An initial assessment of the evaluation undertaken shows how the tool presented here can be used. Most notably, the intuitive ease of use—a product of their direct coupling, the continuous workflow, and the resulting integrity of idea, model, and sketch—changes the way people think and work. What was particularly apparent is that real-time feedback makes it possible to make more changes, see
DANCING ON THE DESKTOP: GESTURE MODELING SYSTEM TO AUGMENT DESIGN COGNITION

ABSTRACT

During the design process, architects have traditionally used a range of media and tools, including sketches and physical models, to create external representations that communicate design concepts. These representations are rapid, support quick testing and advancement of ideas, and allow new patterns and ideas to emerge. However, building these models in computer-aided architectural design (CAAD) programs is cumbersome and time-consuming. In this paper, we take a cognitive perspective to explore how designers distribute part of their spatial reasoning onto the materials and tools with which they work. From this cognitive theory, we have created a unique gesture-based modeling system, Dancing on the Desktop. In this prototype, two interactive displays are projected on a desktop and the adjacent wall to show the plan and perspective views of an architectural model, respectively. Visual images and text are projected on the user’s hands to provide different types of feedback for the gestural interactions. A depth camera detects gestural interactions using these two displays to create an immersive gestural interaction space for model manipulation. We argue that Dancing on the Desktop helps users develop an embodied understanding of the spatial and volumetric properties of virtual objects that the current CAAD systems cannot afford. The details of the low-cost, yet effective, gesture recognition technique are also described in this paper.