

Bridging the Gap

A (Collaborative) Design Platform for early design stages

Gerhard Schubert¹, Eva Artinger², Frank Petzold³, Gudrun Klinker⁴

^{1,2,3,4}Technische Universität München, Germany

^{1,3}<http://www.ai.ar.tum.de>, ^{2,4}<http://far.in.tum.de>

¹schubert@ai.ar.tum.de, ²artinge@in.tum.de, ³petzold@tum.de, ⁴klinker@in.tum.de

Abstract. The motivation behind the CDP interdisciplinary research project is to resolve the current discrepancy between familiar, analogue ways of working in the early architectural design stages and the ever increasing use of digital tools in office practice. The project's objective is the conception and prototypical realisation of an interactive work environment for use in the early design phases. By directly linking familiar analogue ways of working with digital computer aided design tools, the CDP represents a working environment that allows designers to work the way they are used to while making use of the potential of computers. This paper describes the first results of a design environment for supporting the conceptual phase of urban design.

Keywords. Design Tool; Interactive Simulation; Early Design Stages; Interaction

INTRODUCTION

Despite the increasing use of computers in architectural offices and ever more powerful software and hardware solutions, computers are still only rarely used in the early phases of the design process. This can be attributed to poor human-computer interfaces as well as the limited application scenarios currently available. For designers, complex software and inappropriate working methods constrain creativity and hinder the design process.

As a result, computers are used primarily as digital draughting machines rather than as innovative design tools. Almost 20 years ago, Glanville (1992) wrote that CAAD software manufacturers treat the computer solely as a tool; to exploit its full potential it needs to be understood as a medium. And to the present day, this has not changed fundamentally: "They are all primarily focused on representing a

design which has reached a level of finalisation in its development. They do not really support changing design perspectives" (Gero 2006).

A central aspect of the interdisciplinary "CDP | Collaborative Design Platform" research project, undertaken together with the Chair of Augmented Reality and the Chair of Industrial Design, is the conception of an interactive working environment for the early phases of the architectural design process. Based on the requirements of the concept development phase in an urban design context and the issue of linking digital and analogue domains, the project aims to examine and explore new means of interacting with and using computers for the design process using a prototypical platform. The aim is to bridge the gap between analogue and digital by directly linking analogue models with interactive, digital real-time simulation methods.

Using a modular principle, the user is provided with small digital helper tools for different functions, applications and program facilities that make it possible to flexibly respond to the respective individual requirements of different design tasks, while still working and designing using the familiar, tried and tested means of an analogue working model.

DESIGNING

The process of "designing" is hard to define and describe. While it is, of course, possible to identify several fundamental principles, a single, clear and universally applicable definition is not possible. This is due not least to the fact that it is not a linear process. Rather it is an iterative process based on the generation of variants and the decision processes that follow from these.

It is simpler, by contrast, to identify and classify the tools and media we use to resolve particular design tasks. Gänshirt (1999) divides design tools into six main groups: observation, sketch, design drawing, model, calculation and verbalisation.

All of these tools can be understood as a form of sketching. "Sketches represent a draft or design idea: they are tentative, not fully thought-through [...] ideas, thoughts and visions that need further development and elaboration" (Figra 2003).

They are short, concise representations of an idea that focus on an essential aspect, and a means of what Arnheim (1972) has described as "Visual Thinking". Through the direct expression of a thought in sketch form, thoughts, ideas and potential solutions are made visible. During the act of sketching, the resulting sketch itself is simultaneously received as a new impression, assessed and responded to. Designing can be understood as a kind of dialogue, "a conversation, usually held via a medium such as paper and pencil, with an other (either an actual other or oneself acting as an other) as the conversational partner" (Glanville 1999). The sketch (whether it is an actual sketch, a model or another medium) becomes one's conversational partner, "firing the doodler's enthusiasm, personal research, and commitment" (*Ibid.*).

The choice of tool depends on the respective design task, the design idea and the design stage. The simpler the tool is to use, the less it gets in the way of the actual process of designing. The word "simplicity" is, however, not one that we generally associate with computers. Nevertheless computers are one of the most important influencing factors in the context of designing.

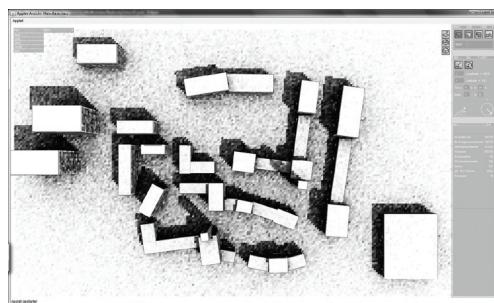
DESIGN SUPPORT

During the design process, architects repeatedly come up against situations that they cannot immediately resolve. Various attempts are made to develop alternative solutions, which are then made more precise, modified, worked up in greater detail or, alternatively, discarded. In assessing which variant is appropriate, architects draw on their own experience and knowledge they have gained as well as refer to calculations, simulations and other sources of information. As such the pen, model and simulation are design tools that serve as a means to an end: the results must be combined with the knowledge and experience of the designer.

To provide support for a design environment, a wide variety of different kinds of program tools are needed. Moreover, these tools must sufficiently assist the designer in exploring ideas based on their own experience and perception. The tools should not impose their will on the designer. Rather they should provide objective assistance that helps the designer to evaluate design variants.

In this context, students developed tools for analysis and simulation in the early design phases of architectural design as part of a semester design project undertaken together with the Chair of Urbanism and Urban Development. The students realized interactive real-time simulation tools for analysing light and shadow, proximity and distance, space and sight lines as well as specific building parameters. Two of the students, Michael Mühlhaus and Nils Seifert, were awarded 5000 € for their project as part of the "Auf IT gebaut – Bauberufe mit Zukunft" [1] prize ("Built on IT – Building jobs with a future"):

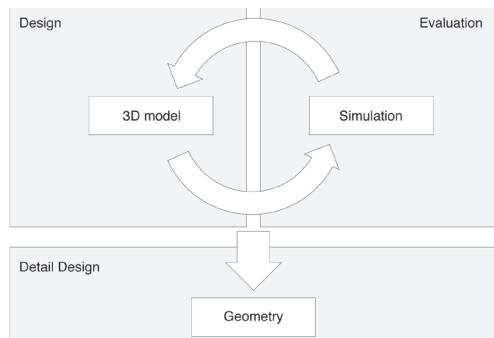
*Figure 1
Software prototype of the analysis and simulation tool for early design stages: interactive, real-time shadow simulation*



With the help of these simple digital tools, simulations that are normally undertaken at the end of the design phase can be applied in order to analyse and assess the implications of design decisions at a much earlier stage in the design process. For example, statutory planning constraints such as building regulations can be incorporated into the design process at an early stage. As a means of optimising the design, they save time and provide objective assistance that can have a direct effect on the quality of the design.

The aim is to simulate tendencies during the early design phases, where the data available is often vague and incomplete, and to display design-relevant parameters with a view to making the spatial quality and functional aspects of a design more legible and the decision-making process more transparent, effective and clear. Such simulation tools provide the designer with additional information that can inform the design but the subjective process of assessment, evaluation and exploration remains in the hands of the architect.

*Figure 2
The creative cycle supported by interactive, real-time simulation tools. Design and evaluation hand in hand.*



One can imagine this as a creative cycle in which the computer provides real-time objective feedback on a variety of relevant issues, which can in turn inform the direction of the architect's design decisions. The boundary between sketch, simulation and analysis blur into a continuous, creative design process.

USER SCENARIO

The task is a competition for a hotel in the centre of a large city: the architect begins with some styrodur rigid foam cut-offs and a knife or cutter and settles down to work.

Rather than working at a computer workstation with pc, mouse and screen, his or her workplace is a multi-touch table. The architect searches for street name and location and loads the competition site on the table top.

While examining the historic surroundings, some initial ideas start to form. Taking a piece of Styrodur, he cuts this to size and places it on the tabletop. An info box appears next to the block showing the estimated building volume and gross floor area. A red icon indicates that the chosen size is not large enough to fulfill the required floor area. The architect takes a second piece of styrodur and places it next to the first. The statutory requirement for inter-building distance is displayed automatically and red areas projected from above onto the styrodur model indicate the areas where buildings are too close together (cf. Projection-based Spatial Displays (Bimber and Raskar)). The architect removes the styrodur block, adjusts its geometry with a knife and places it back in the model. The new form is recognized automatically and the calculation adapted accordingly. The inter-building distance requirements are now fulfilled.

A second colleague takes a look and remarks that a high building in the vicinity may overshadow the new design. The architect changes the display mode and the pattern of shading around the year is shown in colour-coded form. One can immediately see from the massing model of the proposed design for the hotel that it is almost always overshadowed.

Together both colleagues are able to improve on the design, investigating approach routes, views and distances from public transport nodes.

CDP | COLLABORATIVE DESIGN PLATFORM

The basic idea of the Collaborative Design Platform (CDP) lies in facilitating direct interaction between analogue urban massing models and interactive simulations. This means it is possible to work and design using the familiar, tried and tested means of a working model. Additional real-time interaction, allows the designer to immediately assess the impact of design decisions. Examples of this include the real-time simulation of shadow patterns or the real-time analysis of path distances or flow patterns. The simulations provide an indication of implications as a means of supporting the design process. As such the emphasis is on presenting an easily comprehensible visualisation rather than precisely calculated values. This is also appropriate to working with scale models at a scale of 1:500 or smaller where model inaccuracies can easily represent tolerances of a metre or more at true scale.

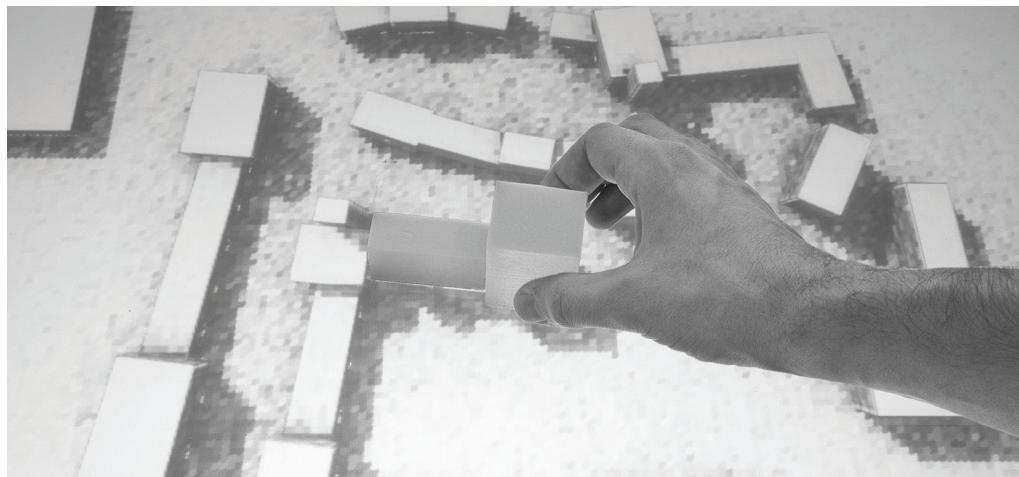
The CDP is conceived as a working tool for the early design phases and assists the designer in developing and assessing design ideas.

Related work

The use of digital simulation tools in combination with large-format tabletops was first discussed more than ten years ago, for example in "Urp: A Luminous-Tangible Workbench for Urban Planning and Design" (Underkoffler and Ishii 1999). Urp made it possible to use analogue models to examine and control interactive simulations, for example for overshadowing and reflections. A marker-based software solution using the software tools "glimpser" and "voodoo" was used to track the objects. For this, however, it was first necessary to construct a 3-D model which was then combined with the markers in the interactive scene. This intermediate stage, however, represents an undesirable interruption in the design process with the result that the tool is used as an interactive presentation tool rather than as a tool to support the design process.

"Pictionaire" is a further example of a tool that likewise uses a large-format interactive table: "It enables multiple designers to fluidly move imagery from the physical to the digital realm; work with found, drawn and captured imagery; organize items into functional collections; and record meeting histories" (Hartmann, Morris 2010). Two additional top-mounted beamers as well as a high-resolution digital

Figure 3
CDP mockup of the user scenario (photomontage): direct interaction between the analogue working model and digital simulation.



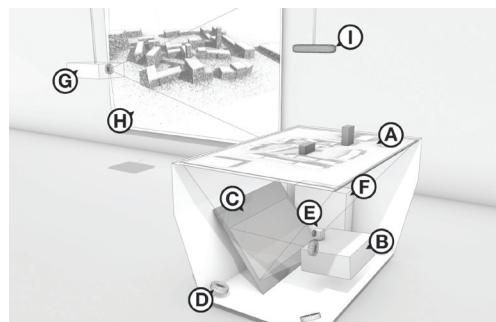
camera provide a technical interface between the two worlds, making it possible to seamlessly interact between the aforementioned analogue approach and digital content. The seamless connection is supported in both directions: analogue → digital by scanning analogue content with a high-resolution camera, and digital → analogue by projecting digital information onto an analogue medium, such as a sketch book.

The aim of the Collaborative Design Platform is to provide a tool that is fully integrated into the working process. Seamless integration is achieved using marker-less, fully automated 3D object recognition in combination with easy-to-understand tools that are kept deliberately simple.

System setup

The basis of the CDP is a custom-built multi-touch table. Together with the Chair of Industrial Design aspects such as ergonomics and working methods were examined and incorporated into the table's design.

*Figure 4
Hardware setup*



The interactive table (158 cm × 96 cm) has a matt projection surface (A) onto which an image is projected from beneath. The high-resolution (1920 × 1080) projected image (B) is reflected by a mirror (C). The projection surface is additionally illuminated by infrared rays (D). An infrared camera (E) takes a picture of the underside of the projection surface as reflected in the mirror (C). The IR camera image captures objects and interactions that touch the

surface. A computer (F) processes the camera data and creates a projection image for the projector (B). The automatic 3D object recognition is achieved using an IR camera (E) in combination with a Microsoft Kinect Camera (I).

Parallel to this, a second beamer (G), that projects onto the screen (H), makes it possible to display further contextual information for the design process such as perspectives or functional diagrams. To provide a better indication of the spatial characteristics, it is also possible to produce true three-dimensional representations of the design. A key criterion for the choice of representation technique is the possibility of offering a true three-dimensional display without the help of optical aids such as shutter glasses or similar. Two different techniques can be used here: one option is the use of auto-stereoscopic screens such as those from Visumotion [2]. A further alternative includes the following solution developed at the Ruhr-Universität Bochum: by using lenticular lens technology, three dimensional representations can be created in a manner similar to the "wiggle pictures" found on postcards that appear to morph when tilted. Here too, artificial aids are not required to perceive the 3D effect [3].

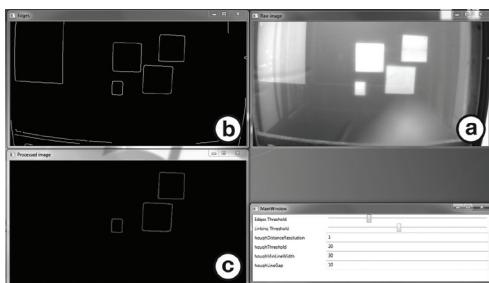
In addition to being able to present contextual information, this additional display is intended primarily for use in collaborative work. Possible scenarios include single-table collaborations as well as spatially distributed collaborations. This makes it possible to display design considerations, or the current state of a remote colleague's design as well as the person themselves via videoconferencing. Subsequent projects will examine in more detail the application areas of CDP in collaborative working processes.

Automatic Object Recognition

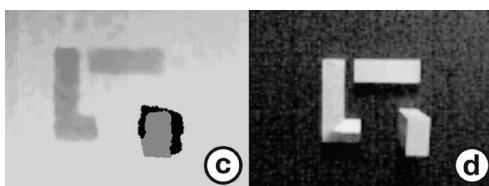
The automatic recognition of the massing of the urban model employs two systems:

1. The basic form of the selected object is captured using an IR camera (E). This facilitates the precise recognition of the basic shape (a). In a

first step (b), object contours are recognised by detecting image contrast. All closed contours are then registered as individual objects (c). To reduce memory usage, object contours are compared with basic primitives, and if within a certain degree of tolerance are stored as such.



2. The 3D massing is captured using a Microsoft Kinect camera (l) [4]. In the initial test setup, the capture of the 3D massing is limited to simple forms without cutouts, which corresponds to the level of detail of a 1:500 scale model. The Microsoft Kinect camera comes with two different imaging systems: a simple VGA-webcam and an infrared sensor. The IR sensor captures the depth and returns a colour-coded image (c) (640×480 pixel) with 11 bit colour depth and an image range of about 5 metres (1 – 6 m), the degree of detail is about 2.5 mm.
- 3.



The combination of two systems offers several advantages: For the geometric recognition system, sections hidden from the Kinect camera image by overshadowing can be compensated for as the height and base area can be scanned independently. Besides being able to work with models and gestures, it is also

possible to interact with other input methods that can be captured from beneath. Additional markers for controlling digital content can be used, for example, for camera movement or to establish the position of the sun. The hardware separation of these input methods means that the 3D digitalisation of gestures and marker recognition can be activated and assessed independently of one another.

On the software side of things, middleware serves as an interface between the hardware configuration and the software applications. This interprets events that are captured by the hardware, i.e. the recognition of inputs in the form of touch gestures or the placement of an object on the table. A TUO [5] protocol is used as a basis for this: "an open framework that defines a common protocol and API for tangible multi-touch surfaces". Software libraries that support TUO include Touchlib [6], reacTIVision [7] and CCV [8], which are currently being assessed according to various predefined criteria. The aim is to unite all input methods – basic forms, 3D object recognition as well as gesture and marker recognition – in a common standard.

OUTLOOK AND EVALUATION

Our Collaborative Design Platform is currently under development. In future, we will test our system with architects as well as architectural students in order to measure the user experience. Our set of participants consists of young students and older architects, allowing us to obtain insight into the behaviour and attitudes of older and younger users. This user set also enables us to assess whether our system meets its intended purpose for both target groups: younger users are more familiar with and open to new technology while older users have more work experience.

Two different qualitative evaluations will be conducted. One will measure the user interface and the other will concentrate on the added value of the analysing tools. In the first evaluation we will explore to what extent the creative design flow is maintained or if it is disturbed by the user interface. The second focuses on the functional added value of the tools, for example the light and shadow tool.

*Figure 5
Basic Shape Recognition with an IR camera (E)*

*Figure 6
3D shape recognition via Microsoft Kinect (l): ir depth image (c) and vga image (d)*

In both evaluations our participants will be asked to perform specific relevant tasks on the table. During our evaluation we will observe non-verbal as well as verbal qualitative user statements. Quantitative data such as task completion time is not the most relevant criteria in our case. It is more interesting to gain knowledge about the user's perception of the system. Does the platform support the architect's work and is the result a success? The "think aloud method" (Tullis and Albert 2008), in which the user says out loud what they are thinking during interaction with the platform, provides us with qualitative information.

After performing the task an interview with open questions will follow in order to find out more about the user's experience. Additionally standard questionnaires like the System Usability Scale (SUS) (Brooke 1996) or the USE questionnaire (Lund) can be used to measure usefulness, satisfaction and ease of use.

SUMMARY

The concept for a working environment for the early phases of the architectural design process presented in this paper bridges the gap between the domains of physical and digital models. The resulting implementation is a new kind of platform that expressly takes into consideration the requirements of the early phases of the design process. By directly linking analogue working models with interactive simulations, it offers a series of digital tools that support the designer while allowing him or her to work creatively with familiar tools and methods.

Alongside the design and conception of digital tools and their integration into the design workflow, future research will focus on more precise object recognition to support free-form shapes and cutouts. A further challenge lies in the conception of the means of interaction offered by the tools described and the manner in which information is visualised for optimal integration in the design workflow. Furthermore, questions about collaborative work, like table-hierarchy and menu-adjustment, will be examined and evaluated.

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- [5] <http://www.tuio.org/>
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- [7] <http://reactivision.sourceforge.net/>
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