Tangible tools for architectural design – seamless integration into the architectural workflow

Gerhard Schubert, Technische Universität München, Chair for Architectural Informatics

Eva Artinger, Technische Universität München, Chair for Augmented Reality

Frank Petzold, Technische Universität München, Chair for Architectural Informatics

Gudrun Klinker, Technische Universität München, Chair for Augmented Reality

Abstract

The starting point for the "CDP" interdisciplinary teaching and research project is to examine how digital tools can be used to support architects in the early design stages. The CDP – Collaborative Design Platform – represents an interface between the familiar and tried and tested ways in which architects work and digital tools that support the design process. The focus of the project concept is to create a working environment that fits seamlessly into the design process. The aim is to close the gap between analogue ways of working and digital tools. Using a prototypical setup, we examine the use of the computer as a tool for supporting the design process.

1 Introduction

Computers have become an integral part of the everyday work of architects. However, if one critically examines how computers are actually used today, one can see that it is mostly only "established" tools and working methods that have been carried over, more or less wholesale, to the computer. The computer is used primarily as a digital drafting machine rather than as an innovative tool. Some 20 years ago, Glanville (1992) noted that CAAD software fails to fully exploit the medium of the computer, using it solely as a tool. And to the present day, this has not changed much 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).

But what prerequisites need to be fulfilled in order to make effective use of computers in the design process? How can the medium of the computer be integrated into architectonic working processes, and support the designer in the design task?

Based on an analysis of the sketching and design process and the tools used, undertaken as part of an interdisciplinary teaching and research project, a work environment was conceived and realised in prototypical form. The focus of the project was to integrate the work environment as seamlessly as possible in workflow of the architect.

The aim is to provide the designer with objective assistance in the form of design-relevant analyses and simulations without interrupting or distracting him from the design process.

2 Designing

Designing is a fundamental part of the work of an architect. But what actually happens in the design process? The sheer number of different design theories shows that it is very difficult to categorically explain what "designing" is. It is no surprise then, that it is even more difficult to structurally define the processes that take place or to incorporate them in a universally applicable schematic framework.

The pragmatic question as to "why most of the 'great' architects are unable to clearly explain how they design, to make it understandable for others, to externalise it…" remains unanswered to the present day, and with it any attempt to structure the intuitive process of designing into a logical, clearly-defined sequence (Schmidt).

Rittel sees the main issue in the fact that architectural problems are usually open-ended problems unlike tasks with clear objectives such as "to fly to the moon and back" (Rittel 1992). Designing is therefore not linear but rather an iterative process that involves the generation of variants and concomitant assessment and decision-making. Its aim is to "devise a form for an object, without having that actual object in front of you." (Gänshirt, 2007).

But the actual question here is: how do I find this unknown object? How does it arise? From this viewpoint, the approach taken by Buxton and Fällman appears much more useful: "Rather than pursue the question 'What is Design' […] let us ask a different (and perhaps better) question: 'What is the archetypal activity of design?'" (Buxton 2007) The almost universal and most readily understandable answer to this question is: "sketching" (ibid.).

2.1 Visual Thinking

But why is this so? The techniques that Leonardo da Vinci used to stimulate the imagination already show how closely interwoven perception and creative thought are (Gänshirt 2007). Assuming that our sensory organs process optical, haptic and acoustic sensations, converting them into electrochemical signals, our brain still has to process such signals into useful information. Seeing and feeling, i.e. our perception, takes place in the brain – a process Otl Aicher calls "analogue seeing" (Aicher 1991).

At the moment of sketching, what is drawn is perceived directly, which in turn simultaneously influences how we think, and changes the sketch as we are in the very process of sketching it. Sketches are short, concise representations of an idea that focus on an essential aspect, and a means of what Arnheim has described as "Visual Thinking" (Arnheim 1971). 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.

"Perception is the first and at the same time fundamental step in any design work" and makes possible the iterative process of externalizing thoughts and their subsequent perception which is so necessary for designing (Gänshirt 2007).

Sketch and model are therefore much more than purely a means of presentation. They can be regarded as thinking tools and pools of ideas. It is their visual feedback that makes it possible to grasp complex design problems and to work on them. This brings us a step closer towards finding an answer to what defines designing. Glanville characterizes designing as 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). It is this internal dialogue that takes place while using tools. They provide feedback and act as the 'conversational partner' bringing about a creative cycle as a result of the feedback provided about what has been created.

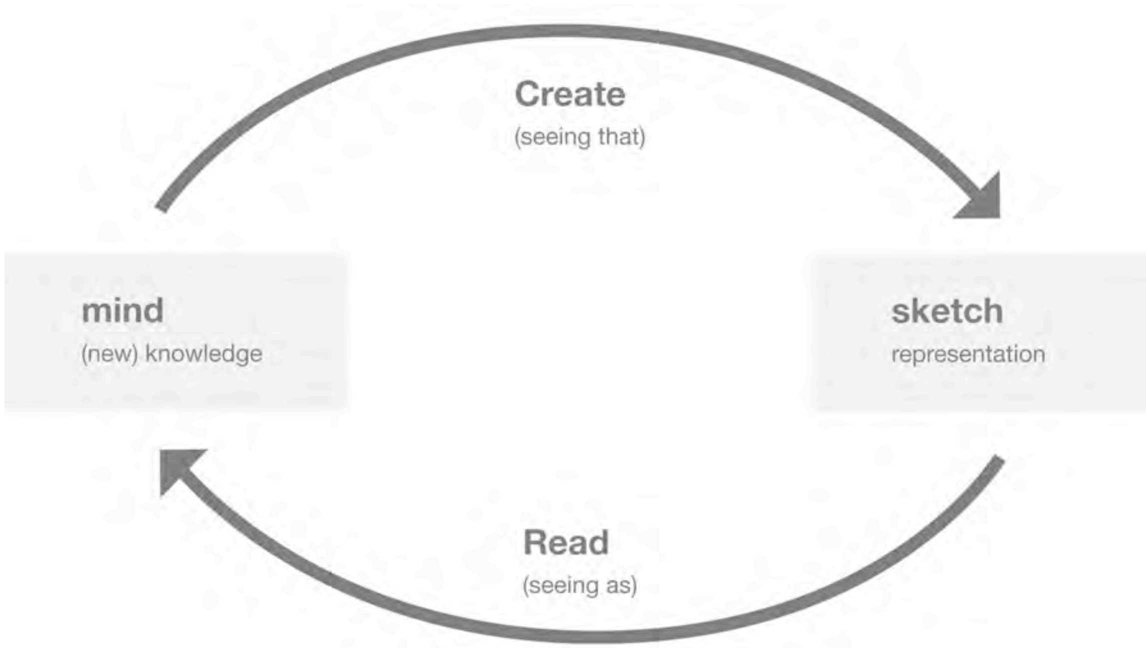

Figure 1 (qt. Buxton 2006). The creative cycle of perception and presentation.

2.2 Design Tools

The process of "sketching" therefore represents an essential aspect of designing, if not its very basis. While the term "sketch" is commonly taken to mean a hand sketch, in our context it is much more than this: "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). In fact all of the established tools can be understood as a form of sketching.

The choice of tool depends on the respective design task, the design idea and the design stage. In general one can say that the simpler the tool is to use, the less it gets in the way of the actual process of designing. Buxton (2006) goes one step further and identifies 11 different key aspects of a sketch which can also, for the most part, be applied to other "tools for thinking". These are: quick, timely, inexpensive, disposable, plentiful, clear vocabulary, distinct gesture, minimal detail, appropriate degree of refinement, suggest and explore rather than confirm, and ambiguity.

Ambiguity as a key characteristic of sketching and the connected phenomena of "emergence" is of particular relevance in our case, as it enables us to interpret things we have not yet thought of in the sketch – in effect to see more, or other things, than what was originally envisaged: "If you want to get the most out of a sketch, you need to leave big enough holes" (Gero 2006; Buxton 2006).

Creative ideas do not arise out of "nothing". They develop out of a dialogue with ourselves that is often only revealed through the use of an appropriate medium. In this respect, if we examine the concept of an IT-tool that supports the design process, the following key criteria could apply:

- Support for idea finding in the early design stages
- Use as a tool for thinking
- Ability to cope with ambiguity
- No distraction or interruption of the design process

3 Design Support

But why should we design with the computer?

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.

For both categories – context-related and human-related – tools have been devised and realised in prototypical form as part of a semester course together with the chair of urbanism and urban development. The analysis and simulation tools, which are integrated in the design environment and function in real-time, create decision spaces that assist the designer in assessing design variants. The use of such tools helps avoid structural weaknesses in the planning process. 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. The students realized 4 interactive real-time simulation tools in prototypical form:

- Light and shadow
- Access and distances
- Space and views
- Specific building information

Two of our students, Michael Mühlhaus and Nils Seifert, won first prize in the competition "Auf IT gebaut – Bauberufe mit Zukunft" ("Built on IT – Building jobs with a future", BWMI 2011).

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. 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 blurs into a continuous, creative design process.

4 7 ± 2 | Seamless integration into the architectural workflow

As described above, designing is a process of brainstorming and exploration. By way of explanation, the human memory is divided into 3 different parts: the sensory register, short-term memory and long-term memory (Gegenfurtner 2003).

Miller (1956) shows that we are able to hold 7±2 chunks or units of information immediately in our short-term-memory. Each chunk consists of bits of information. Depending on the size of each chunk the amount of information we are able to remember varies. A bit of information could be, for example, single letters. If we group the letters to words and therefore increase the number of bits per chunk, each chunk contains more information, which can be remembered more easily than single letters. If words are grouped to sentences and each sentence represents one chunk, it is possible to remember even more information.

During the design process, the architect is already occupied with his or her creative thoughts. Every additional piece of information he needs to remember, for example how to use the software, places incurs greater mental strain. For the interface this means that every action should have a maximum of 7±2 steps; that means every menu element should not exceed 7±2 items so as not to confront the user with too much information. Each element can, in turn have 7±2 submenu entries. The information provided by each element should be as informative as possible to avoid the designer having to reason what the respective command may mean, which would distract from the flow of the design process.

A further special case represents the presentation of the simulation findings. Visualisations that are too complex and overloaded with information force the designer to invest extra attention into deciphering them, distracting him from the actual thinking process. Results that are simple to read and to interpret are, by contrast, taken in almost subconsciously so that one can continue to concentrate on the design process.

5 CDP the platform

If one examines in this context the typical working methods used today in the design process, one can observe the parallel, sequential use of "established" tools on the one hand and digital tools on the other. The individual tools are usually independent of one another so that one has to constantly switch between the analogue and digital tools, consequently interrupting the thought process.

The aim of the project is to resolve this discrepancy and provide the architect with a working tool that, through an integrated workflow, supports the design process by providing objective assistance but without interrupting the thought process. To begin with, we defined the following objectives for the tool:

- Suitable for use as tool for thinking
- Seamless integration into the workflow
- Intuitive human-computer interface
- Provides direct feedback in the form, for example, of analyses and simulations.

5.1 Implementation

The basis of the CDP constitutes a large-format multi-touch table. For the project's construction, we used concepts already familiar from well-known multi-touch tables. The technology used for the table is based on the Diffused Illumination Technique (nuigroup 2011). By using this established technology in combination with a Microsoft Kinect camera, it is possible to realise entirely new means of interaction (Schubert et al.).

A special aspect of our Tangible User Interface (TUI) is the ability to automatically capture 3D objects. This is what facilitates the seamless interface between the digital tool and the architect's familiar way of working by making it possible for a physical working model, as commonly used by architects, to interact directly with interactive design-supporting simulations and analyses in real time.

Figure 2. CDP at work – seamless connection between analogue and digital worlds

In contrast to typical Tangible User Interfaces, the objects are not solely used as an adaptation of the control system (whereby the geometry of the object can usually be ignored – see also Urp (Underkoffler and Ishii 1999)). Through the markerless, direct connection between the physical and digital worlds, the analogue objects are connected to the simulation not just in two dimensions but also as whole volumes, and as such become direct participants in the digital design scenario. A working model made of rigid styrodur foam is automatically scanned in three dimensions and incorporated into the 3D city model. The data basis for the semantic 3D city model is based on an Oracle database in City GML format. Using this newly created digital model, various analyses and simulations can be calculated and the results displayed. Changes to the form of the styrodur blocks, such as when they are trimmed or shaped, or changes to their position are updated directly in the scene, the simulation updating accordingly in real time.

5.2 Software

Based on the aforementioned predefined requirements, a concept for middleware was developed and programmed as part of an interdisciplinary student project. The middleware serves as an interface between the design (in the form of the working model) and the supporting design tools (simulations and analyses) and at present provides the following components:

- Semantic 3D environment based GIS data (Oracle Spatial / Autodesk Maps 3D SDK)
- 3D object capture (Kinect Hack + CCV)

- Gesture recognition as an ‘input device’ (CCV)
- Interface library (WPF)
- Render engine (Open TK)

Based on a modular building block principle, different design-support tools can “dock” onto the middleware. This makes it possible for architecture students in future student projects to be able to develop and program their own tools. For the moment, the scenarios described in section 3 were ported to the system in C# and trials were undertaken.

To make handling as easy as possible, a plugin architecture has been devised. The data exchange – retrieval of the base data on the one hand and communication of the results for display on the other – happens in the middleware. A uniform user interface, and therefore a consistent operating paradigm, is ensured with the help of a central interface library in the middleware.

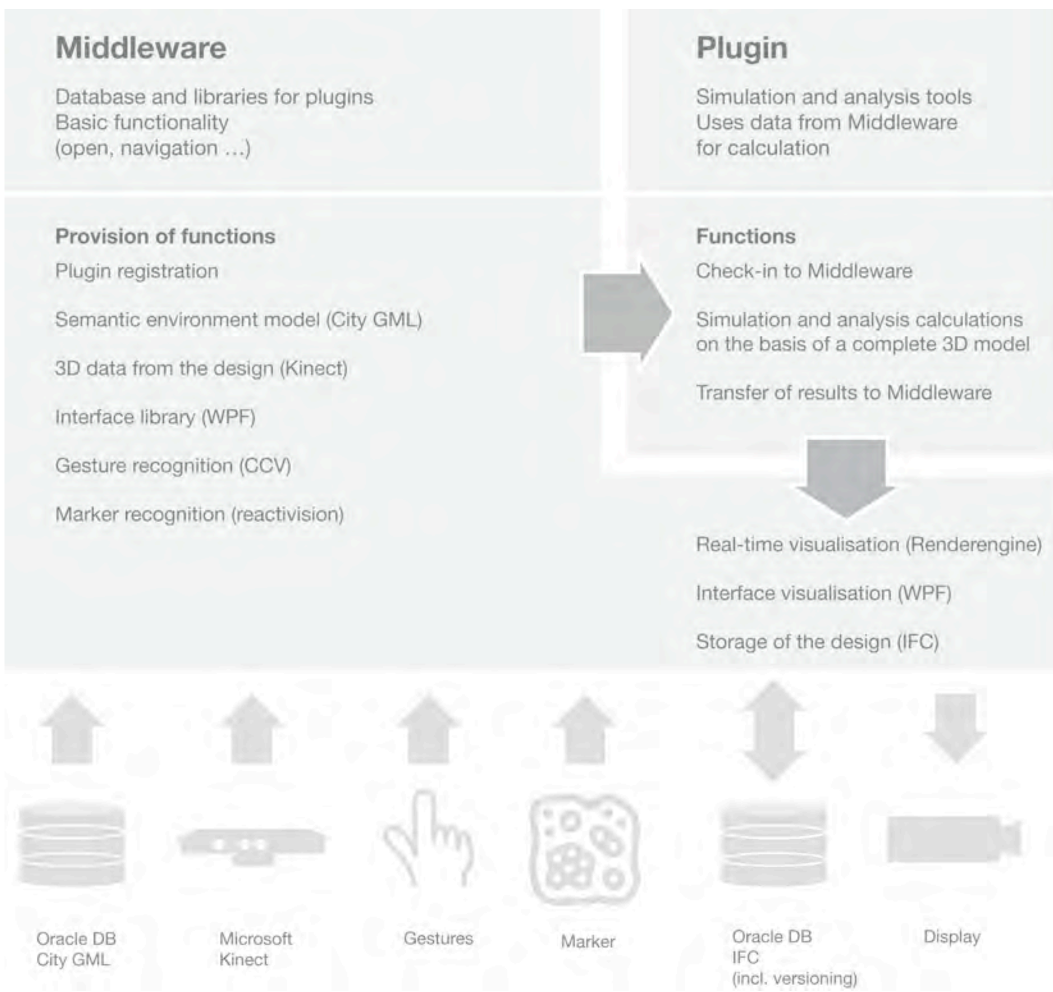

Figure 3. Structure of the software concept with middleware, hardware and plugin architecture

6 Operation / Interface

Designing is a difficult task in itself. As a consequence, the tool's operation and user interface has to be as simple as possible. Don Norman identified "seven principles for transforming difficult tasks into simple ones", which are as follows (Norman 2002):

1) Use both knowledge in the world and knowledge in the head
2) Simplify the structure of the tasks
3) Make things visible: bridge the gulf between execution and evaluation
4) Get the mappings right
5) Exploit the power of constraints, both natural and artificial
6) Design for error
7) When all else fails standardize.

How do these principles translate to a user interface designed to support architects in the creative design phase? In the following each principle (numbered 1-7) is explained more in detail and transferred to the architectural context:

1) There should be consistency between the well-known conceptual model, which is already in the user's head, and the new concept. Norman says "The designer must develop a conceptual model that is appropriate for the user, that captures the important parts of the operation of the device, and that is understandable by the user." (Norman 2002)

   Consequently, known ways in which architects work should be transferred to new concepts. In our case, this is the use of a working model. The styrodur models used for the CDP serve no longer solely visualisation purposes. In the new concept, they become an object that can be used as a means of interaction. Depending on the form of the styrodur, simulations are calculated that present additional supporting information.

2) To simplify the structure of the task Don Norman recommends the use of innovative technology that can provide aids to reduce mental load. To help simplify the architect's complex design process, the system provides additional information such as the calculation of inter-building distances, overshadowing or access paths, so that the architect does not need to keep these in the back of his mind.

3) The gulf of execution is the difference between the user's intention and what is a possible action supported by the system. By contrast, the gulf of evaluation is how easy it is to discover and interpret the current state of the system.

To bridge between these two gulfs, the system should always provide immediate feedback about the state of the system. The user interface should use graphics and words that are immediately understandable to the user.

4) Natural mappings are achieved when the positioning of controls matches the reaction of the objects. They should react analogous to one another. When the architect starts to move the tangible object (in our case the styrodur model), its digital representation should also move in the same direction.

5) The power of constraints reduces the number of possible actions at a particular state of the user interface. Ideally, there should be only one alternative, which is the correct one. This helps the user to stay focussed, because he or she doesn't have to consider several options at the same time. With the help of constraints, desired actions can be made straightforward so that the user knows how to work towards the desired goal without having to consult the manual.

6) To err is human. Consequently, the system should not try to resist errors, because the user will cause them anyway. Error handling consists of two important aspects. The first is to inform the user about the error and how to solve it. The second is the ability to go back and undo an action that may not have been intended.

   In our architectural application all error messages have to be clear, so that the architect is able to understand and respond to them. Additionally, automatic storage of changed states makes it possible to retrace one's steps in single operations to undo any action.

7) If natural mappings and the knowledge of the user are not available for use because nothing like this has ever existed before, the solution is to standardize. In addition, it is most important to remain consistent with standardization throughout the entire system.

   That means that if a cross gesture is used in the system to delete something, that this gesture should always be used for that particular action, whether the user is deleting a file or a scan of the current tangible object.

7 Future Work

The concept presented here for a Collaborative Design Platform as an integrated design environment creates a seamless connection between the familiar, analogue ways in which architects work and the digital tools for supporting the design process.

The CDP forms the basis for further extensive investigations. As part of future research as well as teaching projects, tests will show how well the ideas and considerations outlined here transfer into practice. Of particular interest in this respect is how seamlessly the tool is embedded in the design process and how the concept proposed can really be used in the design phases.

In addition to evaluating the already existing systems, we also intend to realise further conceptual ideas in technical form. The following aspects are currently envisaged:

- Information visualisation

  The real-time presentation of information on the basis of the scanned model data forms the basis for CDP. Future trials will investigate how such calculated information can best be displayed and incorporated into the design process. Highly complex visualisations are distracting, but if the information contained is too sparse, its usefulness suffers.

- Extending the hardware concept

  A central aspect of the CDP is to integrate analogue and digital worlds as closely as possible. Further hardware extensions could potentially improve the degree of interaction and therefore also help minimise the distance between the two realms. By way of example, information could be visualised directly on the model through the use of an additional beamer.

- Evaluation of the interface and operation concept

  At present a study is being undertaken to compare three possible operation paradigms (gestures, markers, menus). The semester project examines these three possibilities with respect to the content that is being manipulated and the operations being performed.

- Collaboration

  Up to now, we have given relatively little consideration to the question of location-bound or spatially distributed ways of working. Some fundamental preliminary considerations have been incorporated and the necessary technical requirements have already been implemented. The possibilities, as well as the limitations, of collaboration is a wide-ranging topic that will be examined in detail in a subproject of its own.

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