Migrating the Classical Pen-and-Paper based Conceptual Sketching of Architecture Plans Towards Computer Tools - Prototype Design and Evaluation

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***Abstract*—While computer-based design tools are widely used in architecure during late design phases for creating final floor plans, early design phases usually still take place in a traditional manner, using pen, paper and scissors. At the beginning of these phases, there is often only a rough idea of how a building should look like. Viewing existing floorplans of similar buildings can help an architect in his/her creative work, but searching for those plans manually is very time-consuming. Automated tools for searching similar floor plans could help to lower the amount of time needed for such investigations tremendously. In order to employ such search mechanisms, proper user interfaces are needed that fit to the architect's working process. These interfaces should be useable easily and naturally, requiring less initial training. They should be capable of creating search requests that can be processed by the attached search mechanism. In this article, we describe two different user interfaces to serve this purpose. We describe their structures and interaction principles. Afterwards we show their general usability and user acceptance by the means of a users study.**

I. Introduction

In the early stages of the design process, the conceptual idea of the envisaged building and its design parameters is still vague and incomplete. While the built environment, the end product of this design process, can be represented concretely in the form of drawings or computer models, the initial design idea can usually only be formulated abstractly, for example as schematic functional descriptions or as topological constellations of spaces and or of relative proportions. A method that is therefore commonly used in the early design phases is to consult reference projects: by drawing on analogies from existing buildings or architectural designs, the designer can verify his or her ideas, identify relevant design parameters or explore new directions and possibilities. As part of a research project (referred as Metis), funded by the German Research Foundation (DFG), innovative research methods are being developed to support design actions in the conceptual design phase. Approaches have been developed for the IT-support and linking of two key design strategies that architects use when developing ideas: functional and conceptual drawings and the use of reference material. Therefore a semantic fingerprint was proposed as a means of characterising a building in much the same way as a fingerprint identifies a person [4]. This same approach can also be used as a mean of formulating architectural situations and in turn for identifying semantic similarities. The semantic fingerprint attempts to address the primary problem of the vague and incomplete nature of design ideas, creating a way of identifying analogous reference examples of existing buildings or building designs. By drawing on analogies from existing buildings or architectural designs, the designer can verify his or her ideas, identify relevant design parameters or explore new directions and possibilities. The core aims of the Metis research project are:

- To find ways of accessing implicit knowledge contained in reference projects
- To formulate knowledge in the form of graphs
- To develop methods and models for retrieving specified formal structures
- To develop a way to specify and to search and retrieve spatial configurations

Working with references is an established methodology in the architectural design process. Functional diagrams and sketches are to formulate initial ideas, for example. In the research project Metis the focus is to formulate queries to the computer, which is the basis for the search in a digital building repository called ”ar:searchbox” (located at TUM). The presented user study examines the extent to which existing prototypes to support the formulation of queries with freehand sketches and functional diagrams can be performed.

However, even till today, architects feel comfortable with pen-and-paper based conceptual sketching. So, as a starting point, a migration from pen-and-paper to simple computer tools is required, in order to achieve further benefits, that are stated as the aims of the project.

In this article, we describe two different graphical user interfaces, that can be used by architects in conceptual design sketching. We first describe the structures and interaction principles of both the presented GUIs. Afterwards we show their general usability and user acceptance by the means of a users study.

The paper is organized as follows. Section II describes the classical style of conceptual sketching. Section III presents

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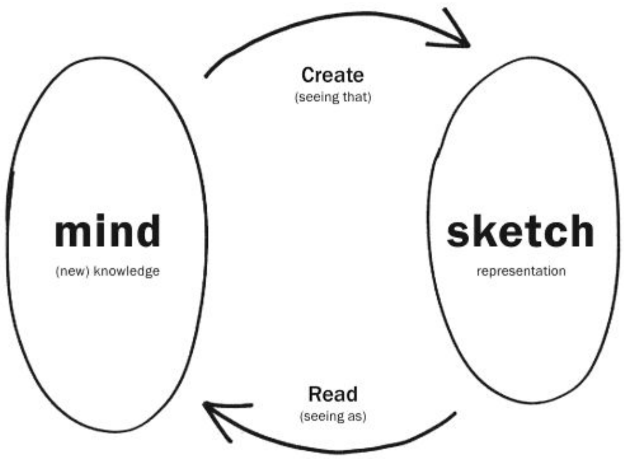

Fig. 1. Sketch of a dialogue with a sketch.

the two different graphics user interfaces for migrating the classical sketching style towards computer tools. Section IV describes the experimental setup for user study. Section V presents the result of the user study and Section VI contains the concluding remarks.

II. Classical Style of Conceptual Sketching

In the design process of architecture various tools and strategies are used. "Every design tool serves the perception of external circumstances (capturing and) as well as the expression of imaginations (the imprinting of inner design concepts onto a physical medium). Every design tool can either be descriptive (which means depicting, describing the given), or prescriptive (which means designing, for displaying something new)." [2]. However, certain tools are more suitable as presentation tool (CAD program or drawing board) and others as thinking tool (freehand drawing or reference). Thinking tools support the rapid materialization of thoughts to perceive and evaluate the materialized fragments of design ideas. The knowledge gained flow into the thought process, and can be described as a kind circular dialogue, as shown in Fig. 1, of the designer with the design tool. Buxton writes: "If you want to get the most out of a sketch, you need to leave big enough holes." [1].

Thinking tools are for example, writing texts, the making of freehand drawings and the use of references as "[...] concrete evidence in support of prediction [...]" [3]. In the early design stages freehand drawings are often used because it is a familiar, efficient and natural way to quickly express and analyze ideas. Freehand drawings can be used to represent unfinished or fragmentary ideas and thoughts, because usually there is still no precise idea of the final result. Gänshirt writes: "The simplicity of the tool enforces to reduce to the essential." [2]

III. Graphical User Interfaces for Conceptual Sketching

We have developed two different digital tools for supporting architects during early design phases: TouchTect and the Metis WebUI.

Fig. 2. Screenshot of the TouchTect UI.

A. TouchTect

Touchtect 2.0 is a Windows application which can be used to query data on multiple web services. It connects to GmlMatcher, Mediatum, Neo4j, the unified-query-service and the bim-server. The application aims at letting this multiple databases look like one. Pen-based interaction on tablet computers and multi-touch tables is supported and give the architect the freedom of expressing ideas intuitively.

In the middle, the free hand sketching canvas support the architect by let him draw a design idea in a schematic way. On the left hand side different queries can be combined like searching for a building that exists in a certain city or one that fits the hand drawing and has seven rooms. On the right hand side a preview of the search results is shown in the form of floor plans. By selecting a result, additional information like pictures and 3D visualisation of the building can be examined.

B. Metis WebUI

The Metis WebUI is a tool that was inspired by a working method called room schedule (or space allocation plan). The idea of a room schedule in architecture is that a set of rooms is given as a requirement for a building (e.g. as a list). Some of these rooms may have a specific size, function, and there may be requirements for neighborhoods of rooms as well as transitions of rooms. It is a more abstract working method than direct sketching but it also used in practice, where a room schedule is usually coming from the customer. Since the architect may have more concrete ideas for some room layouts and rather abstract imaginations about other rooms, we tried to build a tool that supports for multiple abstraction levels allowing for specifying (and respecifying) design aspects as concrete or abstract as desired by the user.

Fig. 3 shows a screenshot of the Metis WebUI. The Metis WebUI runs inside a normal web browser and was entirely written in Javascript. It allows for combining abstract rooms i.e. rooms that are in the so-called bubble mode and concrete room layouts. Within the bubble mode, already the room's size and function can be set, and the room can be interconnected by neighborhood links (displayed as single lines) and passage links (displayed as double lines). If a concrete wall layout exists for a certain room, the user can draw the shape of

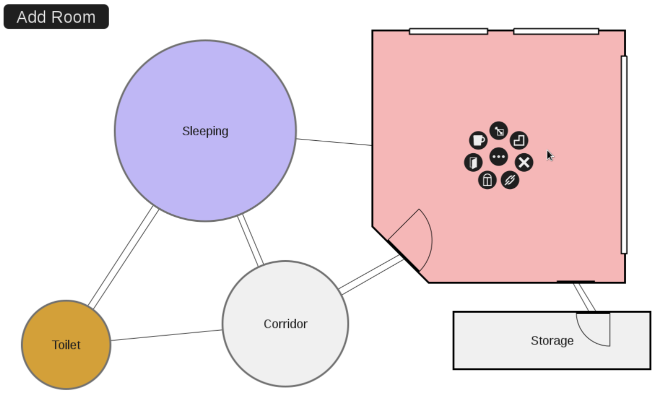

Fig. 3. Screenshot of Metis WebUI showing both rooms with concrete layout and rooms in bubble mode.

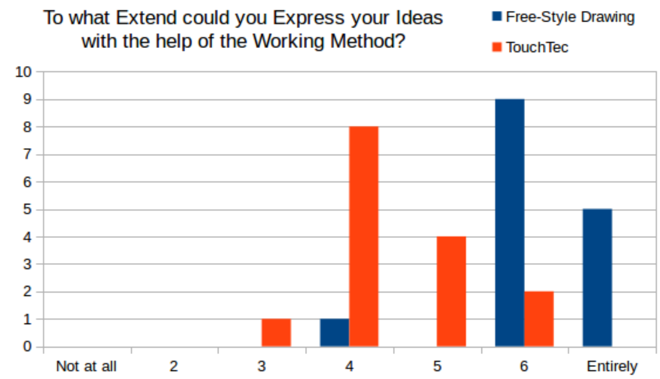

Fig. 4. Expressiveness comparison between Touchtect and Free-Style drawings.

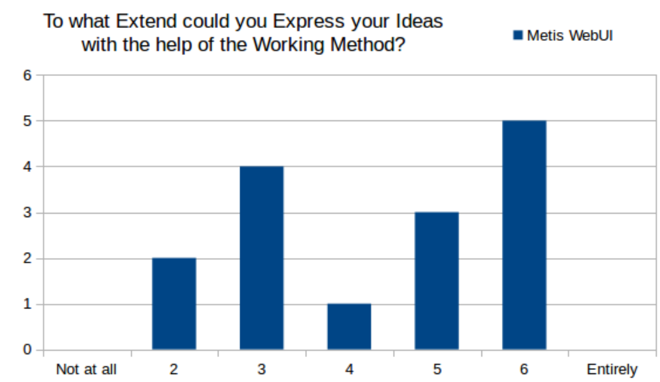

Fig. 5. Expressiveness of the Metis WebUI.

the room and afterwards place windows and doors into the rooms walls. The connections to a room are adopted as they stand when the room is changed from bubble mode to a concrete room layout. Doors and windows can be resized and moved along the walls on which they were cerated. Multiple doors/windows per wall are allowed. Except for one button that creates new rooms, the interface is entirely controlled by radial menus. Single rooms can be moved by mouse and doors can be connected to other rooms or doors by passage links.

IV. Experimental Setup For User Study

We conducted a user study with 15 participants in which we have examined how well humans with architectural background are able to express their ideas in a fictional design process with our user interfaces as compared to established methods. For this purpose, we developed a specific design scenario: to design a rental apartment for a certain price in a big German city from scratch, no restrictions on the ground plan were given. The participants were asked to first create some free-style drawings and then to develop a design based on a space allocation plan. Every task had initially to be done on paper as established method and directly afterwards on one of our user interfaces (TouchTect for the free-style drawing, Metis WebUI for the space allocation plan). The participants had no specific time limit and were rudimentary guided by the study's supervisors. For analysis purposes, the participants were videotaped and asked to fill out a questionnaire. Nearly all of the participants were affiliated with TU Munich and were therefore aware of the Metis projects content. Nevertheless, none of the participants had used the prototypes before the study. With one exception all of the participants are familiar with typical architectural software.

V. Analysis of User Study

One way of evaluating the quality of a user interface is to assess its effectiveness (to what degree was the user capable of archiving his goals at all), its effectivity (how much resources - usually time - did the user need to archive his goals) and its user's satisfaction (to what degree did the user "like" the interface). In order to measure these categories, we conducted a user study in which the participants were asked to perform a open draft task (a situation that fits best to the purpose of the developed prototypes). This experimental design comes with the problem that the final layouts drafted by the participants are not fixed, but depend on their ideas. We could have designed the experiment in a way that the participants should only copy a given floorplan, what would have made the assessment of the effectiveness more easy, but such a task would contradict the intention of the prototypes. But since the participants were asked to first do their drafts on paper and then use the examined prototypes, they usually just copied their previous work.

In order to assess the user's effectiveness, we asked the participants to what degree the constructs displayed on the interface matched their imaginations and to what degree they could express their ideas by using the interfaces (Fig. 4 and Fig. 5). In order to assess the user's satisfaction, we asked the participants to what degree they can imagine to use the tools in real life. For measuring both the user's satisfaction and the effectivity, we asked the participants how exhausting they perceived the work with the examined interfaces (see Fig. 7) and how obstructive the use of mouse and keyboard (Metis WebUI) or the digital pen (TouchTect) was for them and difficult it was to handle them (see Fig. 6).

VI. Conclusion

Basically, most of the participants were capable of entering reasonable drawings using our prototypes. After some training,

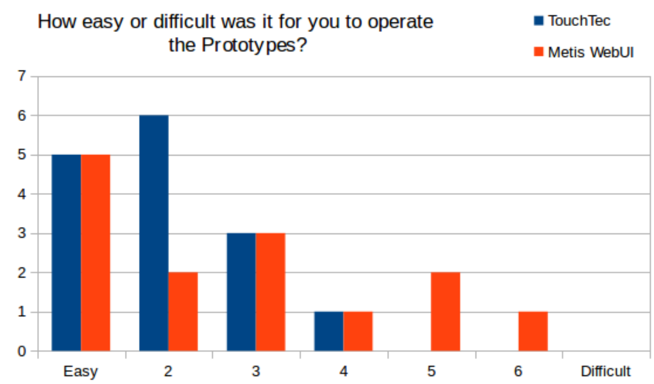

Fig. 6. Difficulty for the users to handle the interfaces.

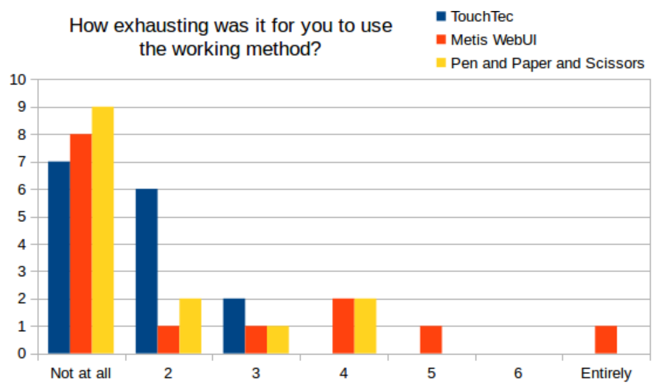

Fig. 7. Exhaustion comparison between the examined interfaces and the classical working methods.

the participants were able to make use of the most functions of the interface and spend reasonable time on handling them. TouchTect with its gestures appeared to be more easy and intuitive to use than the Metis WebUI, especially when it comes to drawing room shapes and linking the rooms. The biggest problem in the context of the Metis WebUI was that most participants did not make fully use of the possibility to connect the rooms as intended but led the rooms unconnected and focused on aligning the rooms manually to each other.

Apart from some rather minor cosmetic and usability flaws that attracted our attention during the study, looking at the way how architects used the Metis WebUI helped us to find some points for design decisions we were not totally sure of before. For example we decided in the examined prototype that the radial menus of doors and windows should only be accessible after pressing the corresponding button in the main radial menu of the room in order to reduce the amount of buttons simultaneously displayed on the room. When looking at the videos we realized that this slowed down and annoyed the participants tremendously. Therefore, we are going to display the radial menu buttons of windows and doors in the next version of the prototype whenever the room is focused. Likewise, the resizing functionality for concrete rooms is unformed: Every room alone can be resized in stepless fashion, but room shapes can only be edited using a fixed grid (we wanted to avoid free-style drawings in the Metis WebUI). Hence, rooms can be resized so that their room length does not fit any longer the ones of other rooms. In the next version of the Metis WebUI we want to tackle this problem by a new resizing function that snaps when the wall corners of a room matches the size of a nearby room. Likewise, we want to incorporate a general snapping function for room movements. Snapped walls may be considered to be automatically connected by links which would speed up the drafting process and would appear more natural to the user. Additionally, a function that automatically links walls of snapped rooms (and even automatically creates missing doors when rooms snap) is planned for future prototypes. A general problem arises, when considering the purpose of the interfaces: The tools can be either considered as a general (and possibly independent) drawing and thinking tool or as the interface to a search engine for similar floorplans. These purposes might diverge as illustrated with the link-drawing issue: The connecting lines have a certain meaning for a later-attached search mechanism. If these lines have another meaning in the mental model of the user (or the user isn't even aware of their existence), the user might think he/she expressed his/her thoughts correctly, but will get incongruous search result. The users should be aware these semantics when the tools are considered as a search interface. Hence, we considered the interfaces as drawing and thinking tools when asking the participants to what degree the display matched their imaginations.

Apart of the evaluated free hand drawings and the modeling of spatial schemata, other paradigms like floor plan representations and zoning of shapes will be examined in the future. Moreover multimodal interaction strategies are necessary to let the architect freely use different abstractions of his/her design idea without interrupting the design process and lost of data. An additional user study involving a test of the prototypes including the search functionality is also thinkable.

The discussed prototype Metis WebUI as well as the TouchTect application are going to be combined with the retrieval system MetisCBR during the further Metis project development. The system uses the case-based reasoning (CBR) technique to retrieve the most similar semantic fingerprints to a given sketch from a case base (a special sort of a database). It is also based on the multi agent retrieval paradigm, where each retrieval agents task is to use the given similarity functions to retrieve the most similar fingerprint parts (such as rooms or their outer connections). The retrieval process will be controlled by a coordinator agent that is able to act as a case- and/or rule-based reasoner to find the best strategy for a particular user query.

Acknowledgment

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