

Towards a Data-Structure that can Handle Ambiguous Information in a Computer-Aided Tool for the Early Phase of Architectural Design

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ABSTRACT

The goal of our research is to develop a computer system that supports an architect in the early phase of the design process. We envision a system that aids in three ways. It helps the architect in maintaining an overview of the development of his or her ideas over time. It shows the current state of the process in a restructured representation. It supports and stimulates the generation of new associations whenever required.

The difficulty lies in linking up with the rich information structure of the architect and the various cognitive processes he or she uses to handle this information structure. The consequence is that the system must be able to include all design content, to interpret it, but not to restrict the architect in his or her creativity. Moreover, the system should stimulate creativity.

We conducted an experiment to get better insight in what the architect provides as input for the system in the early phase of the design process. Several difficulties have been encountered, which we discuss along with possible solutions for managing the data. The system makes use of user-defined relations and system-defined relations. With these relations we can represent the design content in a comprehensive network that we call the Idea Space. This Idea Space is the basis for above-mentioned functionality. In this paper we focus on the (textual) input provided by the architect. In order to get better insight in the ideas and relations made by the architect, in other words the input for the system, we conducted an experiment. Several difficulties were encountered, which we discuss along with possible solutions for managing the data.

1 INTRODUCTION

1.1 Architectural Design Aided Approach

Ambiguity, uncertainty and parallel lines of thought are central to the early phase of the design process. In really connecting with and supporting the architect in this phase, by means of a computer system, we propose to organise the information as the architect does (Segers et al. 2001). This computer system must aid the architect in three ways: in maintaining an overview of the development of the architect's ideas over time, in showing the current state of the process in a restructured representation, and in supporting and stimulating the generation of new associations whenever required.

In DDSS2000 we compared different existing tools for the early phase of the design process (Segers et al. 2000). What is often missing in current CAAD tools is that the design data processed has no explicit relation to the brief, the context, or the situation of the design, while as much as possible of information related to the assignment is needed. Starting from the brief, the architect constructs both the design and a set of new requirements, rules, and demands for the design. All information at hand – some of it not relevant to the assignment – influences the architect in the design process. Everything can be or become relevant. Design solutions lead to new problems to be solved and the continuation of the design process provides the architect with more information on the design assignment and with that a different viewpoint on problems and decisions made earlier. While Schön (1983) refers to the design process as a construction or a dialogue, Witt (2000) talks about story telling.

The rich structure captured from paper resembles part of what is in the architect's head (Suwa et al. 1999). The paper forms an extension to the memory and ideas are constructed on the fly in a situated way. Generally in design research, a lot of emphasis is put on the use of sketches, while the use of text in architectural designing is underestimated. The architect uses normal language to express his or her ideas in the early phase; definitely not only jargon is used. The construction of design concepts can involve the use of metaphors or analogy, and the brief does not necessarily include domain-specific terms. Lawson and Loke (1997) state that the use of words seems to be 'more flexible than pictures in sustaining multiple meanings, and are employed by many designers in conceptualising designs.'

Suwa et al. (1998) state that sketches serve three purposes, however we feel that other representations, like text, work in the same way for the architect. First, representations on paper provide an external memory in which to leave ideas for later inspection. (As the design process continues the set of new requirements and new design ideas form a changing basis from which decisions are made.) Second, representations on paper serve as a provider of visual cues for association of functional issues. (Ambiguity contributes to that, providing multiple meanings of the design representations.) Third, representations serve as a physical setting in which functional (and conceptual) thoughts are constructed on the fly in a situated way (new combinations of representations lead to new ideas or viewpoints).

Simoff and Maher (1998) stress the importance of multimedia in design information. In ontology-based multimedia data mining for design information retrieval, they have an approach closely related to set theory. Relations are made between keywords or indices, which are extracted from a multimedia design database. These relations are semantic relationships, which are synonymy, identity, antonymy, complementarity, and substitutability. With these relations a dynamic approximation of design domain knowledge can be formed.

Stahl (1992) applied another approach to multimedia in a computer aided architectural design in HERMES. He makes a treelike structure containing all design data. The advantage is that the ideas are expressed without being complete. In first instance ideas, as they are constructed, may be largely un-interpreted at the time they are initially constructed. His idea is to save the dialogue, i.e. all considerations and

decisions, in a complex design process to an archive, which contains all representations. His intention is, in a complex design process, to be able to retrieve, at all times, why decisions in the design were made in a particular way and see what considerations and questions played a role in the process of designing. A drawback however is that design information is not captured real-time. The architect needs to make an effort to put this information in the system.

1.2 Computer Aided Architectural Design System

Our intention is to make a computer system that aids the architect in the early phase of the design process, which can be characterized by story telling and constructing the design. The difficulty lies in linking up with the rich information structure that the architect constructs during the design process and the various cognitive processes he or she uses to handle this information structure. Of this rich information structure the system can only use the representations. All design data, and all small parts of the construction that the architect makes contribute to the design. Moreover, the architect may even reuse parts that were crossed through, initially. The consequence is that the system must be able to include all design content. Actually, what we are saying is that the information structure that is captured by the system is like a frame of reference. Without a frame of reference, one cannot tell stories, have a dialogue or build a construction, as in designing.

In terms of a semantic network, the representations of the ideas are the nodes, and the relations between the representations of the ideas are the links. In the system, ideas can be represented in multiple ways: text, sketch, or image. Relations are divided into two groups: user- and system-defined relations. This way it forms an information structure, which resembles a frame of reference. We call it the Idea Space.

We defined three types of user-defined relations. These are time-based relations, place-based relations, and gestures. Time indicates the time of action (project, date, time), and place indicates on which 'sheet' the architect has done his/her action. A gesture is a mark put on paper by the architect, which connects ideas in an intentional manner, i.e., an arrow, an encircling, or a treelike structure. The first two relations are important because then the order in which ideas occur and the fact that ideas were placed near each other is known. This indicates that they were associated with each other, or will be. The third one is gestures. The architect can use gestures to directly influence or change relations between ideas.

Besides the fact that words contribute to sustain multiple meanings in conceptualising the design, as indicated by Lawson, an extra advantage of words is that they can more easily be recognised and related to each other, by a computer system, than other representations can. We therefore use the words jotted down by the architect as an extra handle to form connections in a network of design data: system-defined relations. Like Simoff and Maher we use semantic relations, but we add lexical relations to that. As we see it, architects not only use jargon, but natural language is one of the means to express ideas. We don't intend to build design domain

knowledge in the system. It should make use of a representation of a frame of reference, which is not necessarily related to domain-specific subjects. In relating these ideas we then need to implement a thesaurus. For this purpose we found WordNet®. WordNet is an online lexical reference system, developed at Princeton University, whose design is inspired by current psycholinguistic theories of human lexical memory (Miller et al. 1990). Thus WordNet enables us to more easily connect words in meaning (semantic or lexical).

The focus in this research is on aiding in associative reasoning. The system should stimulate creativity by allowing free generation and exploration of the design data. The envisioned system is able to generate new associations, to relate and restructure information, and to keep track of all ideas made explicit. WordPlot is a first prototype, which is able to name the relations between two words in a semantic and lexical way.

In order to get better insight in the ideas and relations made by the architect, in other words the input for the system, we conducted an experiment. Several difficulties were encountered, which we discuss along with possible solutions for managing the data.

2 METHOD

2.1 General methodology

The goal of the experiment is to get better insight in the input of different architects in the early phase of the design process. Kavakli et al (1999) have described cognitive actions while sketching, categorized into four main groups (each consisting of a number of sub-groups): physical, perceptual, functional, and conceptual. We use some of these categories in the analysis.

Our system will be implemented in the Visual Interaction Platform (VIP-system), developed by Aliakseyue et al. (2000). We have therefore chosen to focus on the physical actions of the architect mainly. VIP handles input given on paper and on tablet. Small Scale Models (Maquette) and three-dimensional computer models are not possible in the system (yet), so these representations were not included in the experiment.

Kavakli et al. divided the physical actions in drawing, looking, and moving. For our purposes drawing, or sketching is not enough. In our experiment we paid attention to four physical activities, related to the different representations that the architect uses. These are sketching, writing text, use of images, and making gestures.

2.2 Working method

Eleven students in the final phase of their study in Architectural Design have taken part in the design experiment. An envelope containing the design assignment, and two

pages with information on the two clients involved in the assignment was given three or four days in advance. It included images of the ground floor plan of the site, images related to the clients, such as interiors of buildings owned by these 'clients', and logos. Opening and looking at the assignment was optional, but sketching or writing anything in advance was not allowed.

Before starting the design-assignment a short introduction of the research and of the experiment itself was given. The setup of the experiment was as follows: one observer sat with each student. The observer had to write down all actions of the architect during the design session. The design session took approximately half an hour. Each minute the time was mentioned. The observations were put in tables. The design was made on transparent sheets. After all sessions, the content of the observation tables and the information on the transparent sheets were collected to analyze.

2.2.1 The Assignment

The design assignment for the architectural students was to design an Internet chair for a large department store in the Netherlands. The assignment was formulated as follows:

“The board would like to improve popularity amongst young people. Therefore, they decided to cooperate with EasyInternetCafé in order to make a new department in the Bijenkorf-Eindhoven under the name of EasyInternetCafé. It will be situated near Café B on the Ground Floor (see Figure 1). Normally EasyInternetCafé is a very busy place. Here however, it has to have the stylish look of Bijenkorf, the new fashionable style, which is kind of trendy. Only five people will be able to use this place at the same time. The board thinks of large chairs in a nicely decorated room. It should have the same relaxing atmosphere as in a 'lounge' club. The measurements of the space are about 5x10 m². The assignment is to think of a concept and style for a particular chair with a contemporary design in order to be attractive for young customers. Such chairs should allow the user to have a good sitting position. These chairs should allow the users to relax and at the same time use the Internet. The computer should be integrated in the Internet chair. Deviation from the assignment is allowed, only it must be substantiated.”

2.2.2 Observation

The observer had to write down all actions performed by the architect in the design session. The observations were put in tables (see Figure 2). There were four items to be filled in the table, namely 'time', 'action', 'location', and 'description'. Each minute the 'time' was mentioned and should be written down. The 'actions' were T (= text, writing), S (= sketch, sketching), I (= image, inserting or making a reference), and G (= gesture, encircling, enframing, drawing arrows, lines that are not part of a sketch, etc.). In 'location' the observer had to put where on the sheet of transparent paper the designer did the action, and on which sheet of paper. In 'description' the content of the actions had to be written down.

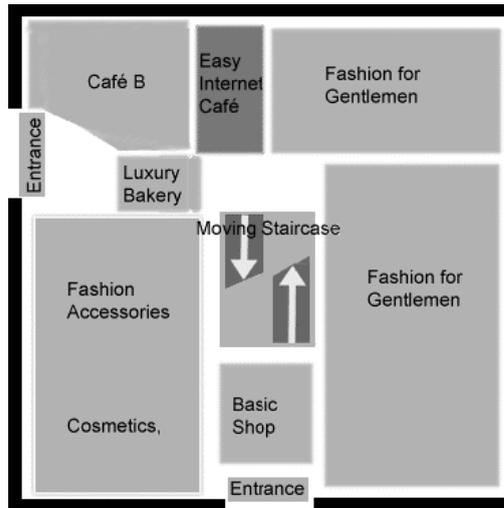


Figure 1: Ground Floor Bijenkorf

time	description						
0.01	Arrow between 'wheel' and the sketch						
action							
T/S/I/G							
location							
<table border="1"> <tr> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td>x</td> <td></td> </tr> </table>					x		
	x						
page 1							

Figure 2: Example of an observation

2.2.3 Analysis

The observations and transparent sheets were analyzed, and the results were put in a large table for each architectural student with observer. In order to be able to reproduce or use the architects' input for processing later on, we need to capture as much as possible. There were eleven items to be filled in this table, which can be divided in three groups. First, the time and order that an action was made and the (relative) position on the paper are needed (time and place). Second, it is important to know what representation, what type, what style, and – if necessary – what direction is used (appearance). Third, the content and a description of what is done in the action complete the analysis (content).

In Table 1 and Figure 3 an example is given. Figure 3 displays a part of the first page of one of the students. It consists of seven actions. First, on the left is an arrow, directed to the right with a single arrowhead. This arrow was the sixth action on this page. Last displayed in Figure 3 is action thirteen, which says 'surfing the Internet in a Roman way'. In Table 1 the tenth, eleventh, and twelfth action are displayed, which are respectively sketch, text and gesture. Action ten is sketching, with a depiction a person lying on a sofa, seen from the side. Underneath the sketch, the word 'Relax' is written, and then to the right an arrow is drawn. The arrow has a single arrowhead and the line of the arrow is single. Further, the arrow is put between two words, and the direction is to the right.



Figure 3: Part of a transparent sheet used in the design-experiment

3 RESULTS

The physical actions we observed were sketching, writing text, use of images, and making gestures. In the observations, it was found that each student used these representations. However differences were found in the amount of writing and the amount of sketching done while doing the assignment.

Sketch was used in several ways. The advantage of transparent sheets is that it is possible to overlay. In sketching this was done regularly. There are three different types of sketches to be distinguished: small icons or diagrams, an isometric or perspective representation, and a projection or section representation.

In the observation we considered two different kinds of images referred to: images that were included in the assignment, and images that were not. The latter referred to a book, a magazine, or the Internet.

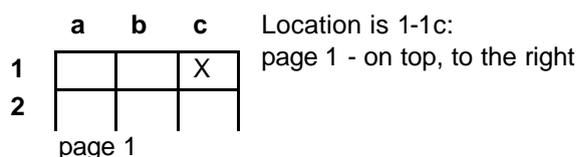
The use, and the amount of text differed greatly among the subjects. Mostly text was put as annotations; these were actually made adjoining all representations. Writing could be done sometimes as a numbered or bulleted list of items. The style of writing could also be found to be in a diagram-like way, namely with keywords. Sometimes the text would contain complete sentences.

The gestures are closely observed. The type of the gestures varied from an arrow, line, encircling to enfaming.

Table 1: Part of the analysis of the transparent sheet in figure 3

Action Number / order	Time passed (minutes)	Location on paper*	Action **	Type	Style	Relative location	Representations	Direction	Color	Description / content
10	1	1-1c	S	projection or section representation	-	right from text	-	-	black	person lying on a sofa.
11	1	1-1c	T	annotation	first cap, lower case	below sketch	-	-	black	'relax'
12	1	1-1c	G	arrow, single arrow-head	single line	between	T and T	left to right	black	between 'relax' and 'Roman'

*The paper was divided in 6 parts:



- ** T (= text, writing)
 S (= sketch, sketching)
 I (= image, inserting or making a reference)
 G (= gesture, making a gesture)

Arrows, for instance, can be double, hooked, or have a treelike structure. The use of gestures such as '+', 'x', '-', '=', '!', and '?' was remarkable. The way they were used indicated that they were gestures, although they are symbols from text. These gestures all had a different appearance in style, relative location, direction, and they were used between different representations. We found the following styles for gestures: single line, double line, multiple lines, dotted lines, and waved lines. The use of color and thickness of the pencil used might be important to state as well. As one might guess, relative locations were: above, under, between, in front of, behind, through, and around. Directions of arrows were (combinations of) left, right, down, and up.

Further, we paid attention to the order that actions were performed, and the absolute location on the transparent sheet of where the actions took place.

4 DISCUSSION

4.1 Observations and Guidelines

Despite the fact that all architects have their own way of generating and exploring ideas, some observations applied to all architects. Guidelines can be formulated starting from these general observations.

Images are important during the design process. They are used to clarify or illustrate an idea, to give inspiration to the architect, or to trace. During the design process different kinds of images can be referred to. It is important to be able to track back when, and where this image was exactly found. Images are related to the other representations only through user-defined relations: in time, in place, and by gestures.

The other representations or actions are more difficult to deal with. Sketches for instance, never seem to be finished. Architects edit them in a later phase, or use them as underlying sketch to trace some of the old lines and add new ones. We intent to solve this problem, by letting the system conclude that the sketching action has finished, as soon as the architect shifts from a sketch-action to another action. Every modification to the sketch, after having done another action, is interpreted by the system as a new sketch. It is then saved and all the earlier versions of the sketch are then referred to in the database (either if the sketch is done again on the same location, or the architect retrieves it). This way a history of how the sketch was built up is also preserved. The advantage is that every sketch-action can be undone easily, and the architect can continue working on an older version of the sketch.

Gestures all appeared to have a different appearance and a different function, depending on what they connected, and how and where they were placed. Next to time and place, a gesture defines another user-defined link between representations. The arrow with a single arrowhead has multiple intentions: the arrow mostly points at conclusions, solutions, questions or other important issues. If the architect uses a lot of arrows connecting other representations, the arrows indicate a design workflow. In or near a sketch, this arrow indicates an entrance, a line of sight, or a movement, circulation, or rotation. Double arrow-headed arrows, often have the same meaning as single arrow-headed arrows. Some extra meaning can be attached to this arrow. Either an analogy is made, or the arrow indicates opposites or contrasting ideas.

There are more gestures to be mentioned. A single line separates information on the working field, if it is relatively long. This separating line can have any direction. If a line is placed under text this line's intention is underlining instead of separating. Underlining indicates an emphasis on something. Underlining is horizontal in most cases. The more lines are used to underline, the more importance the issue underlined has. Encircling or enframing indicate emphasis as well, but are also used to group items on the working field. In the system, the importance is indicated as an extra property of the text-item that is underlined, encircled or enframed. Other gestures that were not so obvious as being gestures are crossing through – as if something is wrongly made – and text-symbols. The text-symbols that

were used as gestures, we call special gestures. For example '=' indicates equalness, and '+' indicates ideas are being combined.

In the system the separation line does not have any influence on the user-defined relations, for items, separated with a separating line still can be associated with each other, since they are situated next to each other. With crossing through it is not our intention to delete information, since it might still be needed later, even though the information seems to be useless at the time of deleting. Therefore this gesture does not create a user-defined relation.

It turned out that the order of actions makes a difference in interpretation of the actions. Writing some text after having made a gesture normally means an annotation is connected by a gesture to something else. But when a gesture is between two sketches, it is unclear if this gesture is not part of the sketch. When a gesture is placed through a sketch it does not necessarily have to mean that it is part of the sketch. For now this is the only interpretation we considered.

The way that text was used differed greatly. Sometimes text was used as annotation, which can be made with all representations. Annotations have as function to clarify a sketch, text, image, or gesture. Other types of writing that were applied, were a list of items (with numbers or bullets), a diagram-like placement of keywords, or a text with complete sentences. A piece of text with complete sentences normally explains ideas more thoroughly. These ideas are mostly statements or concluding remarks. A list of items is mostly used to make a list of attributes to an idea, while a diagram-like placement of keywords is often an abstraction.

In dealing with all the input and process it to useful data, text plays a very important role. The system makes use of user-defined relations and system-defined relations. With these we can represent the design content in a gigantic network that we call the Idea Space. The text is used to form the system-defined relations. First of all, keywords are searched for by the system. These are then checked for any lexical or semantic relation with the aid of WordNet, which is implemented in the system. Whereas other representations are only connected with user-defined links, the words use extra linkage. This extra linkage provides us with extra possibilities, namely the generation of meaningful relations between words and the generation of new associations. Further, words are used to retrieve earlier-made design information in an easy way, as the architect may remember keywords, or annotations that he/she has put with sketches or images.

4.2 Implementation

From this list of guidelines we concentrate on the textual input. We are now implementing the part of the system, where WordNet is used to find relations between words. This part of the system is called WordPlot. WordPlot is able to find synonyms, antonyms, hypernyms, and holonyms. A synonym is a lexical relation between word forms: two expressions are synonymous in a linguistic context C if the substitution of one for the other in C does not alter the truth-value. An antonym is quite the opposite. Both a hypernym and a holonym are semantic relations between word meanings.

While a hypernym is the super ordinate, a holonym indicates a whole. These semantic relations generate a hierarchical semantic structure.

WordPlot assists the architect in associative reasoning by providing new ideas or approaches in the design process, unexpected combinations of ideas, summaries or overviews of current ideas. If we allow WordPlot to generate one intermediary word in relating with hypernyms and holonyms, we feel that this extra-generated word is often quite meaningful to the architect as feedback.

4.3 Future Work

We have found that WordPlot makes a lot of relations between the words that the architect has jotted down. However not all relations are useful as feedback for the architect. Filters will have to be defined in order to decrease the amount of relations given. The relations generated by WordPlot will be shown to all architectural students that took place in the design experiment. Their comments will be used, along with the analysis of the type of relations formed, and the regularities and structures found in the data. These filters will make it possible to provide the architect with feedback, which is meaningful and not too extensive.

Furthermore, WordNet contains pointers from one word to another, with words that are semantically or lexically related. However, it does not contain pointers that include relations, meaningful to the architect in another way. Maybe the system might learn that certain keywords are related according to the architect. In the system a 'counter', which tracks the number of occurrences in which two keywords were connected by a gesture, could be included. After a certain number of occurrences the system adds this link as a learned link.

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