TOWARDS COMPUTER-AIDED SUPPORT OF ASSOCIATIVE REASONING IN THE EARLY PHASE OF ARCHITECTURAL DESIGN.

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Abstract. The early phase of the design process is a seemingly chaotic, complex process, involving many methods and representations. In supporting this process, a computer system that can follow the architect in his/her actions may be helpful. Such a system should assist architects in maintaining an overview of the development of their ideas over time, show the current state of the process, and support and stimulate the generation of new associations whenever required. This paper will discuss the rich information structure in the design process and cognitive processes handling this structure. Further there will be a discussion on the features of a system that can handle this rich information.

1. Introduction

Architectural design in the early phase is characterised by many different faces: it is a seemingly chaotic, complex process, involving many methods and representations. Architects try to get a grip on the assignment, generate and explore their very first ideas. The design information that is useful to the architect in the early phase of the design process can be information concerning the assignment, the situation of the building to be, a vision about architecture, notions and ideas concerning the assignment, etc. While many tools and systems exist that aim at automating or supporting the design process, design aids that make use of this information and with that stimulate creativity, are still relatively scarce. We agree however with Stahl’s statement that ‘computers can support human creativity in design rather than automating or rigidifying the design process’ (Stahl, 1992). The aim of the paper is to present the development of such a system.

In this paper we will discuss the rich information structure in the design process and creative cognitive processes handling this structure. In addition, we will discuss the features of a system that can handle this rich information.
2. Support in the Early Design Phase

(Schön, 1983) stresses the constructive nature of designing. The designer takes a construction of the totality of notions and relations, as the reality of the world in which he/she designs. Means of constructing are perception, appreciation, language and active manipulation. Personal interest, intuition and critique play an important role. Therefore it is important to develop a tool that can be personalised. This personal world, in which the architect designs, can be represented by a frame of reference or an idea-space in the design system. With several cognitive processes one can stimulate creativity in generating and exploring structures that include the very first ideas in this idea-space towards a design-result.

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<th>Design aiding System</th>
<th>Cognitive process (in the head)</th>
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<td><strong>nodes</strong></td>
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In terms of a semantic network, the ideas are the nodes and the relations to the other ideas are the links (see Table 1). Both nodes and links have certain properties, which imply the time and date of creation or use, the design-assignment when it was created or used, next to which nodes was the node or link created or used, and content related properties. The envisioned system must be able to tell what kind of ideas and relations it is dealing with, in order to describe the nodes and links. With this totality of nodes and links, it is possible to show the development of ideas in time, to show the current state and to suggest ways to continue via association.
2.1 IDEAS OF THE COGNITIVE PROCESS

The design information that is useful to the architect in the early phase of the design process can be information concerning the assignment, the situation of the building to be, a vision about architecture, notions, and ideas concerning the assignment. (Finke et al., 1992) have defined cognitive structures used in creative cognition, and of particular importance are those cognitive structures that are called pre-inventive structures. These are used to represent novel visual patterns, object forms, mental blends (conceptual combinations, metaphors and blended mental images), category exemplars, mental models, and verbal combinations. These structures are internal representations that may be largely un-interpreted at the time they are initially constructed. The pre-inventive structures vary in complexity. They can consist of only one word or notion. Also they can be a concept, consisting of more notions and relations. In the process of creative cognition these structures are generated and explored.

2.2 IDEAS OF THE PHYSICAL PROCESS

Design sketches are considered as important means for a designer. (Suwa et al., 1998) state that sketches serve three purposes. Sketches provide an external memory in which to leave ideas for later inspection. Sketches also serve as providers of visual cues for association of functional issues, and most importantly, sketches serve as a physical setting in which functional thoughts are constructed on the fly in a situated way. In the early phase of the design process, the designer visualises his/her thoughts about the design not only by sketching, but also by writing, working with images and making small-scale models.

Writing in the early phase of the design process, like sketches, also serves many purposes. Firstly, we think of annotations. Annotations with sketches, images, or even text, make some thoughts explicit for clarifying the architect’s intentions. Secondly, text serves to express certain statements, (abstract) concepts or functional issues, which form the motive or inducement for the further development of ideas. Thirdly, the architect uses text to structure or organise design thoughts or information about the assignment.

The relative use of writing, working with images and making small-scale models differs from architect to architect.

2.3 RELATIONS OF THE COGNITIVE PROCESS

Creative cognitive processes serve to generate and explore the pre-inventive structures. The pre-inventive structures can be altered, changed or related to other structures. Ways of doing so are making changes in attributes or contexts, or making combinations with one or several other structures. In all cases new
relations are formed. We found that in order to describe the relations, we can make a distinction in these relations according to set theory: identical, subset, union, mutually exclusive, complement, and intersection. This comes close to what Simoff and Maher have done (1998).

They describe the semantic relationships as being synonymy, identity, antonymy, complementarity, and substitutability, in order to make the relations non-hierarchical.

Subset means that the pre-inventive structure is part of another structure or the other way around. One could think of ‘culture’ and ‘art’. As we see it Identical and synonymy are special cases of subset. Union refers to the combination of two or more pre-inventive structures, becoming something different. Here we can think of a ‘triangle’ and a ‘circle’ can be placed together that they resemble an ‘ice-cream’. Mutually exclusive implies that the structures have nothing to do with one another. Complement means that two pre-inventive structures are exactly opposite. For instance, ‘public’ can be opposed to ‘private’. Intersection means that two or more pre-inventive structures have something in common, but are not equal in all aspects. ‘Composer’ and ‘video-artist’ have in common that in both cases they are ‘people that produce art’. Antonymy expresses in a more general sense opposition, then mutually exclusive, complement and intersection.

2.4 RELATIONS OF THE PHYSICAL PROCESS

As said, sketching and writing serve many purposes. In making thoughts physical or making a physical setting, one can continue constructing on the design process more easily. The physical relations serve the same purpose. Designers make a lot of marks like arrows, references on paper. They encircle or outline elements, put some elements closer together or make diagrams. These are ways of making the relations of the elements or notions explicit. These marks and ways of handling the physical elements can serve as a hint for how information is ordered inside the architect’s head.

3. Illustration

In order to better understand design and getting a grip on what kind of associations and creative thinking takes place in the early phase or the architectural design process, we interviewed architects about their work methods and conducted three design-sessions by ourselves.

In figure 1 can be seen that the architect jots down a lot of annotations with sketches and writings in the early phase of the design process to express the ideas and to support the generation and exploration of new ideas. The architect needs to get things ordered in concepts and change the way things are put
together in order to make associations, mental transformations and to think of how to apply or use ideas. In the early phase of the design process, there are still many changes and nothing is fixed. This makes it easy for the architect to think ‘freely’, to drop ideas and to relate to new ideas.

Figure 1 gives examples of relationships, associations made by the architect in the second design session. Several times, the architect made an association, by thinking of a slightly different expression, or a synonym and was then able to make an abstraction or a conception about the design-ideas, which lead to further steps.

To elaborate on the example in figure 2: the basis thought for the architect was ‘private’ vs. ‘public’ (complements). In the brief is expressed that the future-owners both love nature and culture (mutually exclusive). The architect searched for ways of interpreting this. ‘Love for nature’ can be translated to ‘a view to nature’ (subset) at many places in the building. But interpreting ‘love for culture’ was more difficult. The future-owners are a composer and a video artist. This was interpreted as ‘making culture’ (shift meaning slightly, subset). Because of the fact that the brief says that they want to show their work to friends, this working and entertaining can be seen in the public part (subset). Opposite of ‘public part’ is ‘private part’. Relating to the previous: opposite to ‘making culture’ is ‘perceiving culture’ (antonymy or complement). Since the ‘public part’ is ‘extravert’ (performances for friends, subset), continuing in opposites: the ‘private part’ must be ‘introvert’ (also subset). This has had influence on the shape of these parts of the building. But it has had also influence on what kind of culture will be perceived. ‘Introvert’ was related to ‘culture or art’ as being ‘books’ (subset). And thus the function of ‘library’ was added to the brief (intersection).
4. Creative Cognition

In the design process, different cognitive thinking-processes alternate in order to develop the design, including abstraction, association, reasoning, etc. But not all is based on a conscious manipulation of ideas. Probing is very important in designing (Schön, 1983). This may lead to so-called unexpected discoveries while sketching or writing. As (Suwa, Gero and Purcell 1999) state, the changing context and developing list of requirements contribute to the movement from one idea to the next as well as combining ideas that have not been paid attention to simultaneously yet. To relate ideas, Goel (1999) identified as so-called lateral transformations. A lateral transformation moves the architect from one idea to a slightly different idea rather than refining or detailing the same idea.

A useful conceptual framework for structuring design processes and finding the separate ideas and relations can be found in cognitive science. Finke, Ward and Smith (1992) approached the study of creativity through a method called creative cognition. Creative cognition consists of a set of mental processes, each of which helps to set the stage for creative insight and discovery. In creative cognition, a difference is made between the generation of cognitive structures and the exploration of the creative implications of these structures. Intermediate results serve as means for the exploration of the cognitive structures. These intermediate results are called pre-inventive structures.
Sketches, small models, (pieces of) text could be seen as pre-inventive structures.

Summarising, the generation of pre-inventive structures is based on the combination of ideas, rearrangement or changing of the ideas. The ideas can be single concepts, contexts or parts. The exploration of pre-inventive structures is mostly based on searching, re-interpreting, and imagining the use. These processes form new ideas and relations.

5. The Idea-Space

5.1 IDEAS AND NODES

Architects can find ideas anywhere. It is important to be able to interpret and divide the ideas into nodes. The design support we envision integrates and inter-relates textual, graphical, and other information into one design information system, or in our terms: the idea-space.

5.2 RELATIONS AND LINKS

For us the most interesting part is the relations in the idea-space. (Stahl, 1992) makes an information network based on relationships in terms of a dialogue. Examples of relations are critics, queries, answers, arguments, justifications, and issues. The system is used to communicate design problems with other people. It does not support making associations and interpretations.

We propose to support the design process by organising the information as the architect does. Although the design process is like a dialogue, according to Schön (1983), and the architect tends to tell himself stories, according to Tom Witt (2000), we contend that the information network should be more like a frame of reference, or idea-space. It is this very frame of reference or idea-space that is being used in making these dialogues or stories. If the structure of nodes and links resemble how in the human mind ideas and relations are present, the information that the designers handle can be stored and retrieved in a more or less natural way.

5.3 THE IDEA-SPACE

The general idea is to capture the construction of the totality of ideas and relations of the architect while he uses the system. These ideas and relations are formed in the head of the architect, but also partially made explicit physically (see Table 1) in multiple representations. To a certain extend, the architect will have to tell the system what he wants to be nodes and links, how his/her ideas and relations should be interpreted.
The aim of the envisioned system is that the architect will be able to create and edit physical ideas and relations. These are then captured by the system and the system attaches higher-level cognitive information to it. The ideas and relations are represented internally as nodes and links. When the architect asks for it, these nodes and links have to be presented to him/her and this presentation can be edited as well. In other words, the architect creates and edits both his/her own physical ideas and relations, and the representing structure of the system, a frame of reference or idea-space, consisting of nodes and links. The higher-level cognitive information consists of nodes and links, with properties assigned to both the nodes and the links.

With this totality of nodes, links, and their properties it is possible to show the development of ideas in time, to show the current state and to suggest ways to continue via association. The architect needs to reflect on his/her design process from time to time. The system can give an overview of the ideas by presenting the nodes and links. In showing the current state in various ways to the architect, he/she can get a slightly different viewpoint on the nodes considered. By showing the structure of nodes and links to the architect, it might reveal gaps in the idea-space. Because of this, generation and exploration of new ideas is stimulated.

Presenting the nodes and links, i.e. the structure without its properties, to the architect can be done in several ways. The properties determine which nodes and links are shown. For example, the properties of time and date, in the nodes and relations, are used by the system to determine how the structure is shown in chronological order. It is complicated to create a system, which is able to show the structure, organised or ordered based on content. Content gets its meaning or possibilities of interpreting, when the context of the ideas and relations is known. So in showing the architects the nodes or links, surrounding nodes and links have to be shown as well. As the architect keeps on using the system, and more ideas and relations are captured, it gets personalised and more useful to the architect. The system will contain more and more ideas and relations, making the structure richer and able to make more suggestions.

The advantages of building an idea-space of nodes and links are to reduce the cognitive load, to inspire the user, and to aid the user in reflecting on his/her conceptual forming in time. As stated above, there are also a few disadvantages to this approach: extra work is required for the architect and it slows down the process and therefore creativity as well. When we informed architects, why they use sketching as means of designing rather than for instance modeling, they all said: ‘Because it is fast!’ One of our main concerns then is to make a system, which advantages outweigh its disadvantages.
6. Discussion

It is not easy to see into the conceptual world of the architect and it is also not easy to capture the ‘physical’ ideas and relations made by the architect. In order to do so, we need to be able to handle ambiguous information, represented by sketch, writings and images. To a certain extent the architect needs to determine what are the nodes and links, since the system is not able to do so. There is a need for a balance between automated determination and user-assisted determination of the kind of nodes and links.

We are considering semantic networks, neural networks, and fuzzy logic to support the envisioned functionality of the system. Interaction with the designer in giving him/her the right (personal) feedback might be supported by a learning mechanism. The system must be able to capture what kinds of ideas and relations are made and how many times. The system needs to give the designer feedback. In presenting the idea-space it is important to consider how the architect will retrieve the information. Optimal would be in more representations, including sketch, writing and images.

We will implement the envisioned system in the Visual Interaction Platform (VIP) of IPO (Aliakseyeu et al., 2000). This is an interaction-device that enables the user to handle both real objects and ‘virtual objects’ at the same time. So the architect will be able to create and edit physical ideas (real objects). The system attaches higher-level cognitive information and presents this to the architect. The nodes and links presented form a ‘virtual object’, which then is projected and can be edited as well.

7. Conclusion

Using the idea-space as basis for the support in the early phase of the design process seems promising. The same can be said about using ontology and semantics to form the framework and basis of the system, in a non-hierarchical and flexible way.

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References


