A MODEL OF DESIGNING THAT INCLUDES ITS SITUATEDNESS

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Abstract. Current models of designing are inadequate as a basis for the development of CAAD tools for use at the conceptual stages of designing. Such models appear to be only satisfactory for the detail stages of designing. Further, current models of designing are not in accord with our present knowledge of designing. This gap has created difficulties in the development of suitable computational support tools for designers. The development of the model proposed in this paper aims to begin to fill that gap and hence provide a foundation for a new generation of computer-based design support tools, potentially applicable at the conceptual stage of designing.

1. Introduction

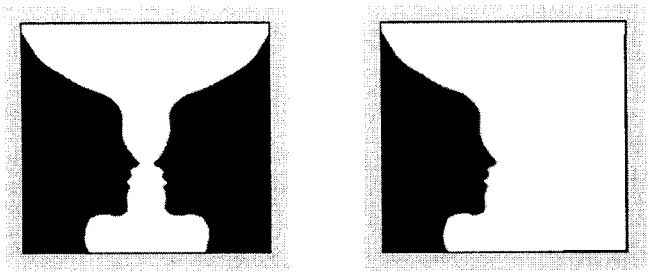
The development of computer-aided architectural design is founded on computational processes that either model human design behavior or processes that intentionally have no connection with human design behavior. Until relatively recently knowledge of designing has come from either well-informed conjectures about how humans design or introspection by designers (Asimov, 1962; Jones and Thornley, 1962; Broadbent, 1973). The introduction of formal methods from logic, mathematics and operations research into models of designing opened up numerous alternate approaches to the treatment of design processes (Alexander, 1964; Mitchell, 1977; Radford and Gero, 1988). More recently, concepts from artificial intelligence have extended the range of approaches available to describe and model designing – both human designing and certain design processes carried out inside computers (Coyne et al, 1990). However, approaches based on artificial intelligence concepts are still largely based on conjectures about putative human designing behaviour. Most recently, tools from cognitive science have started to provide some more insight in human designing (Akin, 1986; Lawson, 1990; Cross, Christiaans and Dorst, 1996).

As we find out more about how humans design we are able to construct models of increasing explanatory power; models which form the basis of computational systems which either mimic designing or provide aids to designing. Computer-aided architectural design has provided few tools that are applicable at the early stages of designing. One possible reason for this may be that the foundations for those tools do not match the cognitive behavior of human designers. In this paper, we introduce recent ideas from cognitive science and design science as possible foundations for different computer-aided

architectural design tools.

2. Recent Insights into Designing

We shall introduce two concepts from cognitive science: situatedness and constructive memory. We will see that design researchers have observed both of these as they studied human designers. *Situatedness* (Clancey, 1997) holds that "where you are when you do what you do matters". This is in contradistinction to many views of knowledge as being unrelated to either its locus or application. Much of artificial intelligence had been based on a static world whereas design has as its major concern the changing of the world within which it operates. Thus, situatedness is concerned with locating everything in a context so that the decisions that are taken are a function of both the situation and the way the situation in constructed or interpreted. The concept of situatedness can be traced back to the work of Bartlett (1932) and Dewey (1896). Situatedness allows for such concepts as emergence to fit within a well-founded and explanatory framework. Figure 1 demonstrates situated emergence – the notion of how a situation affects what can be "seen".



(a) (b)

Figure 1. (a) Two black human-like heads in profile, reflections of each other create the situation where a white vase can be seen to emerge; (b) a single black human-like head on the same background does not create the same situation and therefore no emergent vase can be found.

The emergent white vase does not appear when the situation changes. Further, situatedness can be used to provide the basis of conceptual designing when we introduce another idea from cognitive science, namely that of "constructive memory".

Constructive memory holds that memory is not a static imprint of a sensory experience that is available for later recall through appropriate indexing (Rosenfield, 1988). Rather the sensory experience is stored and the memory of it is constructed in response to any demand on that experience. In this manner, it becomes possible to answer queries about an experience that could not have

been conceived of when that experience occurred. This view of memory fits well with the concept of situatedness. Thus, the memory of an experience may be a function of the situation in which the question, which provokes the construction of that memory, is asked.

One area of design research based on cognitive studies of designers designing that is beginning to be examined is the use of sketches in designing (Eckersley, 1988; Goldschmidt, 1991; Schon and Wiggins, 1992; Suwa and Tversky, 1996; Suwa, Gero and Purcell, 1998). Schon and Wiggins (1992) found that designers use their sketches as more than just external memory, they used them as a basis for reinterpretation of what had been drawn: this maps on to emergence and theirs and other studies provide strong evidence for this form of situated designing. Suwa, Purcell and Gero (1998) have found that designers when sketching revisit their sketches after a while they sometimes make unexpected discoveries, Figure 2.

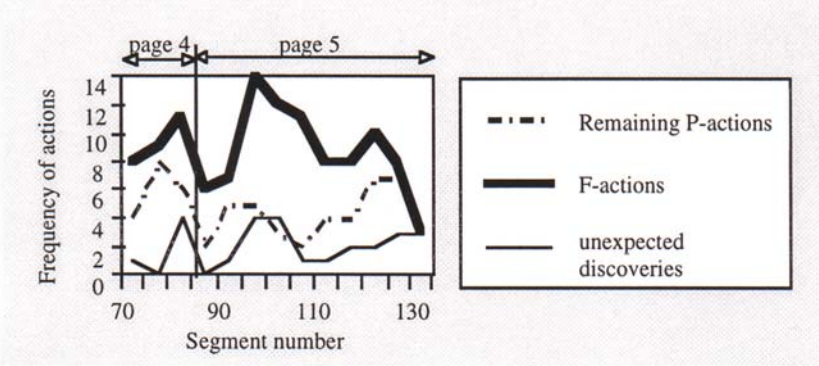


Figure 2. Correlation between unexpected discoveries and functional cognitive actions (F-actions) as opposed to purely perceptual actions (P-actions) in a design session. Segment number refers to the segments in the protocol and the page number refers to the pages of sketching (Suwa, Purcell and Gero, 1998).

They concluded that "sketches serve as a physical setting in which design thoughts are constructed on the fly in a situated way".

Further research (Suwa, Gero and Purcell, 1999) has indicated that designers not only construct their thoughts in a situated manner, but that they also reinterpret what they have already done through the lens of their present conceptions. This is in accord with research on human cognitive behavior. Dewey is quoted as saying:

> *"Sequences of acts are composed such that subsequent experiences categorize and hence give meaning to what was experienced before"* (Clancey, 1997).

3. A Model of Designing That Includes Its Situatedness

We are now in the position where we can lay out the requirements for a model to support computer-aided architectural design that includes the situatedness of designing. A model will have the following features.

- sensory input → sensations
- perceptory processes → perceptions
- conceptory processes → conceptions
- situation construction processes → situations
- memory construction processes → memories

3.1 SENSATIONS

Sensory input comes about computationally when there is a defined, receiving variable. If there is no variable for that "sensation" then that sensation does not exist for the system. Sensations are the equivalent of "sensory experiences". Once received, they are stored and are unchanged. They are always available for other processes. They form one of the bases for the construction of memories. Sensory experience is the same as "fact memory", which is memory that can be directly indexed and does not need to be constructed. For example, sensations may be the simple existence of lines in a drawing.

3.2 PERCEPTIONS

Perceptions are structured sensations and require the existence of structuring or perceptory processes. For example, if the sensations are lines then the perceptions may be that the lines are joined in such a manner that they form a closed space. From any set of sensations a variety of perceptions may be able to be created depending on both the sensations and the available perceptory processes. Which of the perceptory processes is finally succeeds in producing an appropriate structuring is a function of the situation.

3.3 CONCEPTIONS

Conceptions are the grounded (in previous experience) meanings ascribed to the perceptions. They are a function of both the perceptions and the situation. However, as we have stated the perceptions are a function of the situation and as we shall state, the situations are themselves a function of the conceptions, ie there is a recursive relationship between these three ideas.

3.4 SITUATIONS

A situation is that part of the world or context, which a system or subsystem is exposed to, that interacts with it and which as a consequence causes a change in the system or subsystem. Thus, a situation is not simply the context; it must interact with the development of the conception. The context here has to be conceived of very broadly. It includes the context external to the system and needs to include the current perceptions and conceptions as well as the memory of the system. Situations are recursively constructed. Consider Figure 3, where the same sensation produces different conceptions depending on the situation within which it is perceived.

Figure 3. An example of situation. The same stimulus is perceived as an H in (a) or an A in (b) depending on its situation (Gero and Reffat, 1999 after Solso, 1997)

3.5 MEMORIES

In this model we distinguish between two types of memories. The first we call "fact memories" which are homomorphic with sensory experiences or sensations. The second are simply called "memories" and are constructed from the sensory experience, the conceptions and the situation in response to a demand for a memory. Memories are added to the sensory experience and become indistinguishable from them. The effect of this is that notion of memory is that memories are not static "facts" stored waiting to be recalled through some index, rather they are dynamic and are affected by the present situation. Thus, what a designer conceives of a design during some design activity affects his memory

of what he has already done. Hence, we may restate the quote presented in Section 2 attributed to Dewey as:

> *"Subsequent experiences categorize and hence give new meaning to what was experienced before".*

For example, it was noticed by Suwa, Gero and Purcell (1999) that an architect they were studying saw that a visual axis could be conceived as tying two frontages of his design together and subsequently used that to reinterpret what he had already designed in terms of a visual axis. Further, this visual axis became the driving idea for all subsequent designing.

4. Discussion

This paper has brought together a number of ideas derived primarily from cognitive science to develop a verbal model of designing. This model is orthogonal to such models as that proposed by Asimov (1962) for which there is also evidentiary support. The basic idea is that designing is situated and as a consequence is much more of a dynamic activity than has been implied by most other models. The implications of this for the development of computer-aided architectural design tools is quite profound if such tools are to be useful at the early stages of designing. New CAAD tools which have the capacity to support changes in conceptions are required. As a first step such tools should be able to support changes in representation of the artifacts being designed. They should be able to support emergence with its associated re-representations. They should be able to support memory restructuring. And they should be able to support multiple views.

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