CONCURRENT AND RETROSPECTIVE PROTOCOLS AND COMPUTER-AIDED ARCHITECTURAL DESIGN

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Abstract. This paper presents the results of studying human designers using two forms of protocol analysis and examines the implications of the results on computer-aided architectural design systems. It uses and contrasts two types of protocol analyses: concurrent protocols and retrospective protocols. The preliminary results indicate that CAAD tools to be useful at the early stages of designing need to encompass synthesis, analysis and evaluation and be highly integrated.

1. Introduction

Computer aids to architectural design have had the greatest success at the documentation and representation phases of designing. There have been a number of well-developed analysis tools that have been used during the designing process. A number of reasons have been proposed for this lack of use of computer aids. These range from the fundamental difficulty of modeling synthesis processes, through differences in design styles to an inadequate understanding of how humans design, in order to provide appropriate support. As a consequence of the latter views, there is an increasing interest in understanding how human designers design. Part of this interest comes from a need to be able to develop appropriate computational support tools for designers and part from a need to provide a basis for models of designing. Protocol analysis (Ericsson and Simon, 1993) has become the prevailing experimental technique for exploring this understanding of designing (Cross et al, 1996). Two types of protocol studies have been developed: concurrent and retrospective (Dorst and Dijkhuis, 1995). Generally, concurrent protocols focus on the process-oriented aspect of designing, being largely based on the view of information processing proposed by Simon (1992). Retrospective protocols focus on the cognitive content aspect, being concerned associated with the notion of reflection in action proposed by Schön (1983). As a result, concurrent protocols are considered better suited to a bottom-up approach to the development of models of designing, whilst retrospective protocols are used as the basis of the top-down approach. Normally design researchers choose one or other methodology depending on their goals.

This paper describes an experiment to examine the similarities and differences between the results produced by these two approaches in an attempt to connect the designing processes with the cognitive content of designing activity. The results can then be used to propose general characteristics of computer tools that take account of how human designers design.

2. Protocol Studies of Human Designers

During concurrent protocols, also called the "think aloud method", subjects simultaneously design and verbalize their design thoughts. Studies using concurrent protocols reveal details of sequences of information processes reflecting the designer's short-term memory (STM). It is claimed designers can be involved with concurrent protocols without altering their cognitive processes (Ericsson and Simon, 1993). However, some researchers argue that thinking aloud interferes with the thinking processes (Lloyd, Lawson and Scott, 1995).

During retrospective protocols subjects retrieve the trace of the preceding cognitive processes and reveal information preserved partially in STM and partially stored in long-term memory (LTM). Characteristics of human memory may seriously impair the results, so the retrieved data from LTM may have details omitted or may be generated by reasoning rather than recall. As a result, some researchers utilize videotapes of the design session as cues during the retrospective protocols to assist in the recall of the design activity (Suwa, Purcell and Gero, 1998). In this study we combine both methods, and utilize both protocols from a single subject in an extended experiment. As a result, we are in the position to obtain more complete protocols from design sessions than either method alone. If there is substantial agreement between the results from both protocols, then we can have moire confidence in the results.

Gero and Mc Neill (1998) have proposed the most complete of the coding schemes to understand the process-oriented aspects of designing. It consists of problem domains and design strategies highly related to design processes. The information categories proposed by Suwa and Tversky (1997) and developed by Suwa et al (1998) were established to understand the content-oriented aspects of design. They used notions proposed by Larkin and Simon (1987) to define three subclasses to analyze what designers see and possibly think. In this experiment the transcripts of both the concurrent and retrospective parts of the protocol are encoded using both coding schemes. This allows both the concurrent and retrospective protocols to be used not only for process-based analysis but also for content-based analysis. As a consequence it becomes possible to compare and contrast the results obtained by each type of protocol analysis and then to construct a composite view of designing. However, in this paper we only present the results produced by process-oriented coding schemes.

After the collection of data the raw protocol are divided into small units called "segments". The purpose of segmentation is to facilitate the analysis process because the encoding is based on single segment that will belong to one or some of the subclasses of one category in the coding schemes. In recent protocol researches (Gero and Mc Neill, 1998; Suwa, Purcell and Gero, 1998) the protocol is divided along lines of designer's intention and action instead of verbalization events or syntactic markers (Ericsson and Simon, 1993). The designer's intention is interpreted for each segment, and each segment presents one single intention of the designer in design process.

Goldschmidt (1991) proposed a definition of segmentation where the protocol is segmented by the designer's intention in her protocol studies of architects. She divided the design process into “moves” and “arguments”. Moves divide a stream of design activities into the smallest units of design reasoning present, a coherent proposition pertaining to an entity that is being designed. Arguments are the smallest sensible statements about the design or aspects of it, being related to a particular design move. Generally, one move consists of one or two arguments. The scale of segments proposed by Gero and Mc Neill is more like the scale of arguments, whilst the scale of segments proposed by Suwa, Purcell and Gero is more like the scale of moves.

Although the definition is precise it was still vague in its application in terms of how to divide the protocol into appropriate segments in some particular situations. The methods of segmentations in both recent papers (Gero and Mc Neill, 1998; Suwa, Purcell and Gero, 1998) are similar to Goldschmidt's definition, while the relationship between one segment and the encoding code are different. In the Gero and Mc Neill paper, one encoding code corresponds to one segment, so the length of segments is related to the subcategory. In contrast, in the Suwa et al paper, there maybe more than one code in one segment, so the length of subcategory does not affect the segments.

Moreover, the bases of segmentations are different in two coding schemes. The coding schemes proposed by Gero and Mc Neill are principally based on the transcripts, while the schemes proposed by Suwa, Purcell and Gero are essentially based on the designer's action in the video. As a result, the meanings of segmentations are different in two coding schemes. In this study we chose the definition proposed by Gero and Mc Neill.

3. The Experiment

We recruited third year students in Sydney as subjects because this is the first experiment in a series of experiments. Experienced designers will be used in following experiments. The experiment was set up in one of subjects' studios. The major equipment used was two Hi-8 cameras and one microphone with an amplifier.

In order to have both concurrent and retrospective protocols from a single design session, we used four phases: warm-up exercises, think aloud, retrospection and final interview. Two warm-up exercises were used to make the subject accustomed to the methodology to provide valid information. Generally these four phases took about 4 hours.

Each type of protocol has two videotapes: one macroscopic view and one microscopic view. After transcribing the audio part of the videotapes, the raw protocols were encoded by one encoder in this study. There was one ten days break between the first and the second encodings. The discrepancies between them were than encoded again in the arbitrated phrase. To understand the validity of encoding Table 1 was produced. It showed the result of encoding became consistent by the process.

Table 1. Coding consistency between different coding phrases

	First and second coding	Second and arbitrated coding
Concurrent protocol	55 %	85 %
Retrospective protocol	64 %	85 %
Overall	59.5 %	85 %

4. Protocol Analysis Results

4.1 OBSERVED DIFFERENCES

From the results of this experiment we found some differences between the two types of protocols. Concurrent protocols appear to reveal more information in the beginning of the design process because subjects had to keep talking while designing. In retrospective protocols subjects could not adequately remember these early processes even with the help of the video. This period, however, is an important part of problem finding or problem formulation.

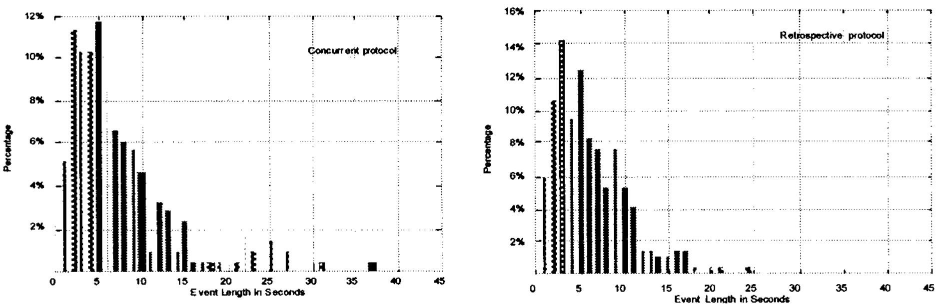
During concurrent protocols sometimes subjects paused their speech. These pauses were regarded as the transition of attention in previous protocol studies, but little information was provided by concurrent protocol. However, we can find some information about these pauses in retrospective protocol because subjects sometimes can recall the thinking process in this period. As a result, both types of protocols have their own advantages and disadvantages. To obtain a more solid comparison we contrasted the results of each type of encoded protocols.

4.2 THE AMOUNT OF INFORMATION

In all our experiments the lengths of retrospective protocols are longer than concurrent protocols, but this does not directly indicate that retrospective protocols could reveal more information than concurrent protocols. The situation may result from subjects having more time to talk during retrospective protocols. Consequently, we used the segments to assess the amount of information in both types of protocols. In this study the segments were divided by designers' intention according to the definition given in Gero and Mc Neill (1998).

After segmentation, the number of segments in the retrospective protocol is more than in the concurrent protocol. For example, in one session the concurrent protocol contained 212 segments while the retrospective protocol contained 267 segments, ie 26 percent more. Since the segments represent the intention of designers, we could argue that retrospective protocols reveal more information.

In order to obtain more detailed information about the design activities of designers, the spectrum of event lengths is plotted to understand how fast designers change their intentions and the abilities of both protocols to reveal the intentions. The speed at which designers change their intentions has obvious implications for CAAD system builders. If designers move through the various processes relatively slowly then CAAD systems can move from one package to another. However, if designers change their focus quickly, then CAAD systems need to have all their packages highly integrated. The spectrums of event lengths from both protocols, Figures 1 (a) and (b), are surprisingly similar to each other.



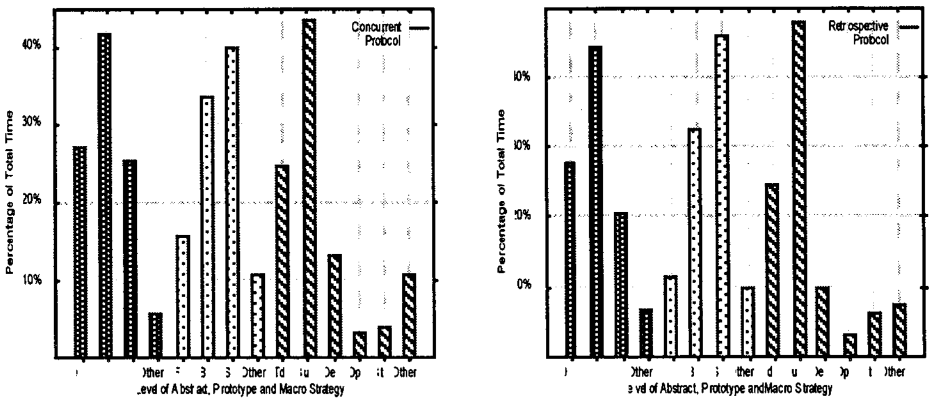
(a) (b)

Figure 1. Spectrum of event lengths; (a) concurrent protocol, and (b) retrospective protocol

The four most frequent event lengths for both of them range from 2 to 5 seconds and the means of the event lengths for the concurrent and retrospective protocols are 7.5 seconds and 6.3 seconds, respectively. The results show that both the concurrent and retrospective are very similar in measuring the frequency of designers' change of intention. The event lengths are surprisingly short. Since it is often the case that one event is followed by an event of a very different kind, CAAD systems which have the capacity to support such designer behavior will need to be highly integrated. In addition, such systems will need to be able to switch from one module to another in a second or less. This implies that such modules will already be loaded and be available at "the click of a mouse".

4.3 DISTRIBUTION OF LEVEL OF ABSTRACTION, PROTOTYPE, AND MICRO STRATEGIES

After encoding we measured the distribution of the various process subcategories. These two concurrent and retrospective protocols were from a single design session, so if they showed different distributions then the different types of protocols could reveal different aspects of designing. The time spent on level of abstraction, prototype and micro strategy is summed for the whole design episode and graphed with other categories in Figure 2.



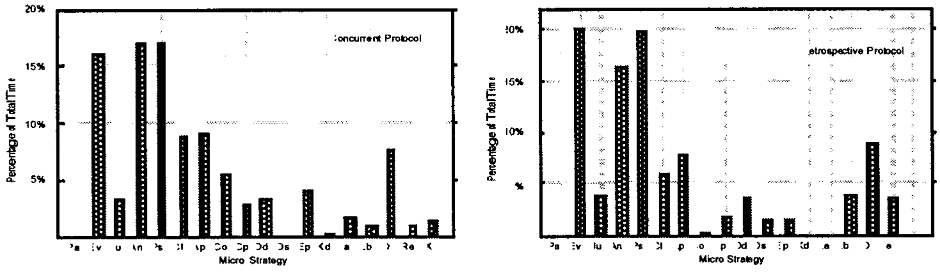
(a) (b)

Figure 2. Distribution by level of abstraction, prototype and micro strategy; (a) concurrent protocol, and (b) retrospective protocol

The time is represented as a percentage of total episode time. These two distributions are very similar and the t test shows there is no difference between these two data.

The time spent on micro strategies is summed for the whole design episode and graphed with other categories in Figure 3. The time is represented as a percentage of total episode time. We can find see some differences between the two protocol methods in these two graphs. From the concurrent protocol, Ap (analyzing the problem), Co (consulting external information) and Ep (evaluation of the problem) occupy a larger proportion than in the retrospective protocol. Ev (evaluating a proposed solution), Re (retracting a previous solution) and Ps (proposing a solution) occupy a larger proportion in retrospective protocol than in the concurrent protocol.

This implies that concurrent protocols may reveal more information related to the functional aspect in design. This period is important to the problem formulation since this is where the requirements of the artifact are generated, in the first instance. In contrast, retrospective protocols may reveal more information relating to producing solutions and evaluating them. This phenomenon may result from the fact that subjects may be concentrating on recalling the thinking process without the interference of sketching and examining as may occur in the think aloud method.



(a) (b)

Figure 3. Distribution of micro strategies; (a) concurrent protocol, and (b) retrospective protocol

In terms of CAAD we can see that the majority of a designer's time is spent (almost 60 per cent) is spent on just three activities: proposing solutions, analysing them and evaluating them. Given the large scale activity they represent, this is a clear focus for any CAAD system.

5. Discussion

In this study we provide some evidence to demonstrate the similarities between concurrent and retrospective protocols. Generally, these two types of protocols are similar in the large scale coding dimension like level of abstract and macro strategy, but some detailed characteristics are different. In concurrent protocols we obtain more data on problem formulation, while in retrospective protocols we can have more information during the period when designers focus on their drawing or examining.

Further, the reliability of the process-oriented analysis was substantiated. The consistency between concurrent and retrospective protocols in this process-oriented coding also increased the validity of using either concurrent protocol or retrospective protocol to understand the design process. Moreover, the coding schemes provide by Gero and Mc Neill (1998) were applied and proved to be robust.

From the analysis of event lengths we know the average duration of events in our experiment is 6-7 seconds. This reflects the speed at which designers changed their focus. In the case of senior designers without verbalization the duration may even be shorter. This phenomenon raises important issues for

CAAD developers, whether the speed of CAAD software can keep up with the speed of the thinking process of architects. This may not a problem concerning computer speed, but rather the speed at which the interface can be reconfigured to match the designer's needs.

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