EXPERIMENTAL RESEARCH ON CREATIVE MODELS

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ABSTRACT

In the area of computation, creative models are classified as combinational, exploratory and transformational creativity models according to the type of procedure used. In this paper, we present a series of contributions on the synthesis process to improve the development of computational models. These contributions were taken from an experimental analysis by applying a model for protocol analysis. The results obtained point to the advantages of considering the three types of computational model procedures simultaneously.

RESUMEN

En el ámbito computacional, los modelos creativos se dividen en modelos combinacionales, exploratorios y transformacionales atendiendo al tipo de procedimiento utilizado. En este artículo, presentamos una serie de aportaciones sobre el proceso de síntesis para mejorar el desarrollo de modelos computacionales. Estas aportaciones se han extraído de un análisis experimental aplicando un modelo para el análisis del protocolo. Los resultados obtenidos indican la conveniencia de considerar procedimientos de los tres tipos de modelos computacionales simultáneamente.

1. INTRODUCTION

Since the publication of several articles covering research carried out by Professors Hideaki Takeda, John Gero and their associates in 1989-1990, positive advances have been made in the development of synthesis models which are not only descriptive, but also computational. Synthesis is the least known stage in the design process, and at the same time the most critical, as it is in this stage that creativity is at work.

Two key aspects in the understanding of this evolution are the abduction model (Takeda et al. 1990) and the Function-Behavior-Structure framework (Umeda et al. 1990).

In brief, the abduction model proposes that solutions are inferred from knowledge and from elements of the initial requirements. In the design process, design requirements and available knowledge cannot be determined in advance but are defined during design, problem definition can be inferred deductively from solutions. So the real design process is defined as process repeating abduction and deduction (Takeda et al 2001).

Maher (1996) used the term co-evolution to consider that the definition of the problem (Function) leads to a solution (Structure) and this solution in turn redefines the problem. Function changing and structure changing are important for tracing design process, but is impossible to model them separately (Dorst & Cross 2001).

The designer's creativity, intelligence and experience play an important role in the abduction process. When we move into the computational field, creative models can be divided, according to the terminology used by Boden (1999), into combinational, exploratory and transformational creativity.

- Combinational creativity: an innovative idea is that of an unusual combination or an association between known ideas, as Case-Based Reasoning (Kolodner, 1993).
- Exploratory methods: sustain a constant evolution of the design space through the extraction of information from search processes. An example of this are evolutionary and adapting computing techniques, (Parmee 2001).
- Transformational methods: can make changes in their own rules and some can also evaluate the novel results, as evolutionary algorithms, that have been applied to creative design to evolve solutions in recent years (Gero 1996).

The aim of our study is to gain a better understanding of the synthesis process and to this end, we have used the protocol technique to analyze how designers design and extract knowledge which enables us to improve the development of computational models based on the co-evolution of the FBS framework and which makes compatible the different kinds of creativity.

An experiment was designed to analyze how designers come up with solutions to a design problem. It sets out to analyze the progress of the structure state through verbal exchange between a group of designers. The experiment was filmed on video for subsequent protocol analysis (Mulet et al, 2001). The design problem was to design a drawing table suitable for working on at home.

2. ANALYSIS OF DESIGN PROTOCOL BY MEANS OF A CREATIVE MODEL

FBS elements in design processes: functions, behaviors and structures were extracted from the protocol analysis.

In order to identify these elements in the design protocol, apart from the verbal exchanges between the participants, a further type of information had to be studied. This information, which helped to shed as much light as possible on the design process, came in the form of the drawings made and the gestures through which the solutions were simulated.

Once this information had been extracted, descriptions of the FBS model at each step of the design process were constructed, known as the FBS state model.

We focus our attention solely on the structure and behaviors that the designers propose in design. Structure specifies what elements the design is composed of, what the attributes of the elements are and how they are related. Behavior appears when designers invoke simulations.

Each time a structure is added or modified, its description is registered in the structure state model or structure model. Each structure is identified with the use of arrows on which other previous structures have been based. In this way, the generation of the structures is shown throughout the design process.

Table 1 shows the first 2 minutes of the protocol. The first column shows the time instant of each structure state. Each structure is identified by the numbers that appear in the second column. The third column contains the design protocol. Figure 1 illustrates the model used that corresponds to the first 17 minutes of the protocol.

Table 1. Structures in the design protocol

Time	S	Protocol
0:30	1	A2: well, so it takes up as little space as possible, better if it's foldable.
0:34	2	A5: I thought about fixing it to the wall, so when you fold it up, there's a ring to hang it onto the wall. A5: and the trickiest bit is the angle
1:05	3	A3: we could attach a piece like this and then it can be adjusted
1:11	4	A5: right, that would be more like a runner type (mentioning what has been seen in class), one piece like this and a spring which holds the board, and you move the lever and it follows the runner

1:24	5	A4: and the board can be completely folded up, and the legs folded too, can't they? When you pull the legs out, it folds like this. A2: three positions: horizontal, angled and completely folded. And then the legs too.
1:43	6	A5: the legs could be tubular, 4 legs like this and some things in the middle, because if you use your foot to fold it you still have to fold it too and it won't stay folded. A3: it might work if it's pulled out like this, the table would be like this with two legs and the legs would go up and it would stay fixed.
2:06	7	A1: or it could be fixed, a frame right, which would stay like that and then you could pull out some leaves, and the legs would go in the main frame.

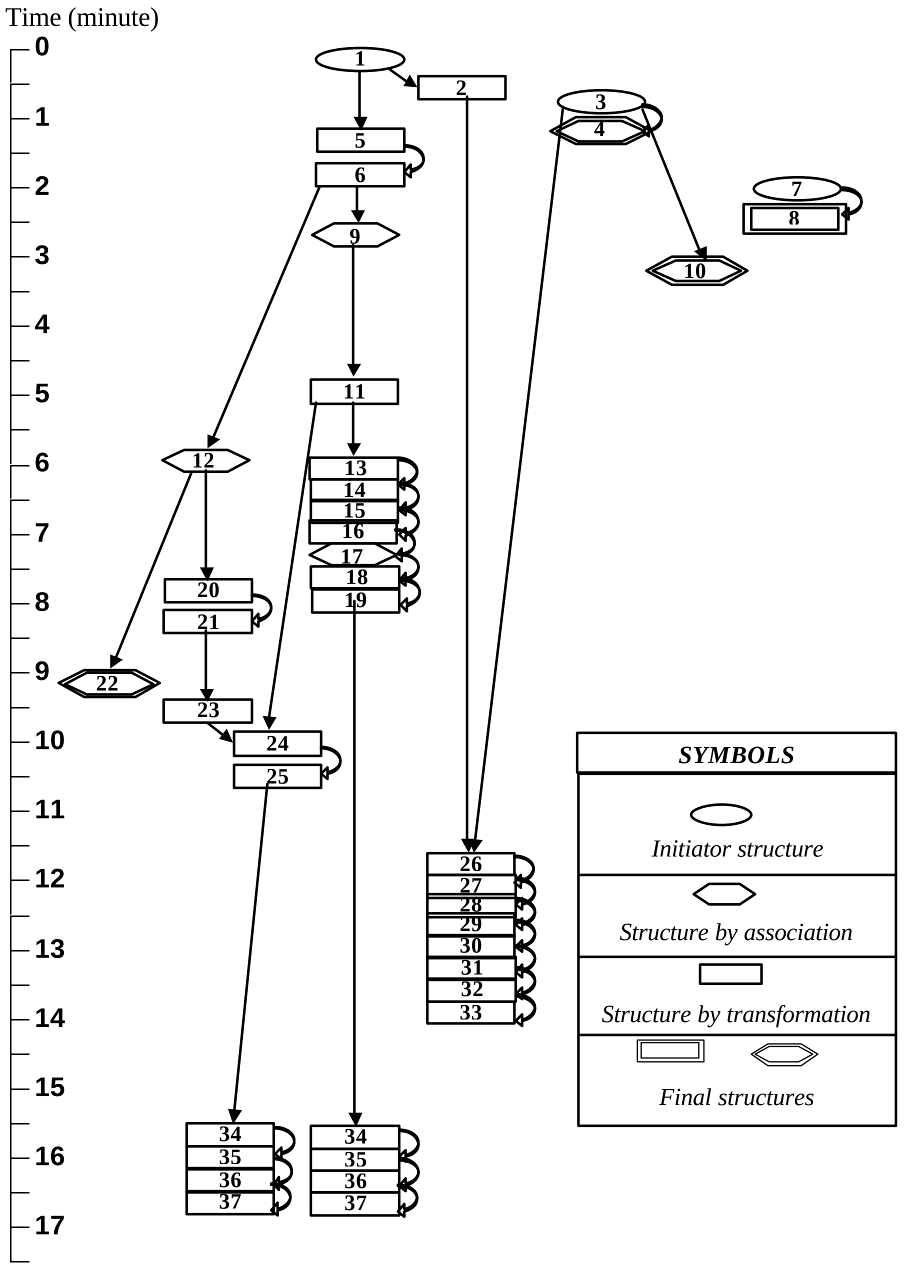

Figure 1. Model of the generation of structures

Four types of structure were identified according to the way in which they were generated: initiator structure, structure by association, structure by transformation and final structure. Each of these types is represented by a symbol.

Initiator structure: this is defined as a structure which is initially thrown up and from which the other structures are formed. Initiator structures are not formed as a result of the other structures suggested during the design process. They come out of the knowledge available at the moment the design is begun, as a result of a search process.

Structure by association: this is defined as a structure which is formed through a process of search for a design followed by associations to apply that design to the problem.

These structures are identified in the design process because explicit reference is made to that design. A first structure consisting of an explicit reference to a different design might, on occasions, appear on starting to design.

Structures by transformation: this is defined as a structure which is formed through the application of various operations, as addition and exchange, on an already formed structure.

The operations carried out when these structures are obtained have been studied. The addition operation is to carry out a search, starting with a previous structure, for a new element which is added to the structure in question. On other occasions, the previous structure is not retained in its entirety throughout the design process, but rather it is partly substituted by other structures that are formed.

This operation is similar to certain operators used in genetic algorithms. Specifically, it is similar to the reproduction of the best fit elements to which new, randomly sought elements are added.

The exchange operation is that in which part of one structure is exchanged for part of a different structure. This operation can be compared to the procedure followed by the crossover operator of genetic algorithms and genetic programming.

Final Structure: the structures and the arrows define a series of paths which advance with time. These paths correspond to the various alternatives of the design. Throughout the design process, there comes a moment for each of the problem alternatives in which structures cease to be formed. This circumstance is shown in the model by a double line around the symbol of the final structure for each alternative.

3. RESULTS

The results of this analysis show that more than one procedure for the formation of structures takes place simultaneously during the design process.

Starting with a small number of initiator structures, new structures by associations are formed, in which use is made of other known structures. However, new structures are also formed by the application of other different operations on structures that exist at a given moment.

Structures by association are not as frequent as structures by transformation. In this particular case, this could be due to the fact that Meccano® pieces were being used to define solutions.

It can also be observed that both procedures for forming structures, without distinction, arise out of a structure obtained by transformation or by association with a known element.

A further aspect to be considered is that certain ramifications occur from an initiator structure. These ramifications are the various design alternatives or path solutions. An example of ramification in figure 1 is that which takes place in structure 6, which consists of folding the legs completely, and at the same time giving them a tubular shape. This structure branches into two. One is structure 9, which consists of using the folding system found in ironing boards. The second is structure 12, which uses the same system to fold the legs as is used to shorten the length of the legs of a tripod.

While the formation of solutions is occurring, the fusion of two previous structures into one is also taking place. The structures which are fused together could come from different paths and give rise to new paths, and therefore new alternatives.

On occasions, an idea is generated which constitutes an improvement that can be applied to more than one solution. In the model, this structure is repeated in more than one path. Structure 34 is an example of this. It consists of attaching wheels to the drawing surface which, once the table is folded up, make it easier to wheel it to its storage place. It was decided that this structure would be applied to two of the solutions that were developed.

As can be seen in figure 1, the fact that search, association and transformation are used simultaneously is what leads to a greater wealth of alternatives. On one hand, the number of solutions is dependent on how many solutions are known. But moreover, the transformation operations applied to form new structures lead to the appearance of new solutions at certain given moments. The formation of design solutions therefore takes place in two interacting ways, and this interaction leads to a greater number of solutions.

The model defined to represent and analyze structure generation is easy to interpret and reveals a good deal of information. However, the modeling of the structure formation process from the data on design protocol presents certain difficulties. Firstly, the initial state of the knowledge at the designers' disposal on the particular design problem is not known. Secondly, the data on protocol do not sufficiently clarify the mechanisms used to obtain the structures.

This means that the structures which give rise to each new structure cannot be identified with total clarity. When a structure is located in the model in relation to previous structures, it is likely that it will have been formed from other knowledge which is not represented. A certain amount of uncertainty also surrounds the identification of the original structures from amongst those that have been obtained from the protocol. This uncertainty can be resolved reasonably successfully by following an in-depth, reiterated analysis of the protocol data.

The identification of the types of structures is also affected by these limitations. There may be a higher number of structures by association than that indicated. This is due to the fact that some of the structures generated might be based on a known design, but that it was not explicitly mentioned. The same occurs in the definition of initiator structures.

4. CONCLUSIONS

A model has been defined which enables us to represent and analyze how structures are obtained during the design process. A series of conclusions can be drawn from this model which could be useful for the computational modeling of the design process.

The algorithms developed to model the creative design process are normally based on one single type of computational model. Either a combinational type model, or an exploratory or a transformational type model is used.

However, the results of this design process analysis reveal that procedures are used which can be related with the three types of computational models. The quantity and quality of the structures generated depend on the knowledge available on structures.

At the same time, they also depend on the operations applied to the previous structures, which give rise to new structures.
Solutions are obtained by carrying out a reiterative process of search and operations. The simultaneous use of different operations enables us to obtain a greater number of design solutions than when only search or transformation or association with known solutions is used. These operations should be used together in the computational algorithms developed to model the design process.

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