Cognitive Principles in a Computational Engineering Design Methodology

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A-Design

A-Design is a multi-agent computational system that automates the conceptual design process and is currently capable of solving several electromechanical design problems (Campbell, Cagan, & Kotovsky, 1999). A-Design takes input and output constraints for a desired electromechanical device and produces an array of conceptual designs that satisfy the problem constraints.

In order to solve a design problem, the system initially generates a population of candidate designs. These candidates are then evaluated along multiple dimensions, and all but the best candidates are eliminated before another iteration of design generation begins. In each iteration of the design process, the best designs from the previous iteration are modified and a number of new designs are also generated. This iterative design process is similar to the iterative design process employed by engineers solving design problems (Smith & Tjandra, 1998).

While A-Design's development was guided by some aspects of human cognition, it is not intended as a cognitive model of the design process. However, it does provide a point of departure for an investigation of the cognitive processes occurring in the field of engineering design. As an initial step in this investigation, modifications were made to A-Design in order to allow it to learn design knowledge during problem solving. A-Design was then tested to see if this learned knowledge could transfer to new design problems.

Learning from Design Experience

A-Design already had the ability to examine a group of designs and extract common subsets of electromechanical components that appear in every design of the group (Campbell, 2001). A set of interconnected components that appears in multiple designs will be referred to as a common subsystem of those designs. In this research, A-Design was said to have completed a design problem after it had run for a specified number of design iterations on that problem. Useful design knowledge was extracted after a problem had been solved by examining the best six designs produced in the final design iteration. Common subsystems were extracted from these designs, and these subsystems were added into a permanent memory store. Subsystems were indexed in this memory by the input and output constraints of the subsystem. A-Design could then add these subsystems to designs that it generated while solving new design problems.

The declarative memory component of ACT-R (Anderson & Lebiere, 1998) was utilized to store these subsystems. The ACT-R model of memory provides the capability to retrieve a chunk based on information in any of its slots, which gives A-Design the capability of retrieving a subsystem based on only a subset of the information contained in the input and output constraints of the subsystem. The ACT-R system may also provide the basis for an expanded version of A-Design which will attempt to capture some of the cognitive processes underlying design.

Results

A-Design was tested on a number of design problems to see if knowledge learned in one problem could be transferred successfully both within and across problems. Results indicate that A-Design applies learned knowledge very successfully in the same design problem where the knowledge was learned, however there is very little successful knowledge transfer across problems. This lack of transfer highlights some aspects of representation and knowledge transfer that A-Design does not have but which human designers obviously do.

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