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POSITION PAPER

TEN PROBLEMS FOR AI IN DESIGN

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Modern design research dates back to the end of the eighteenth century when French theorists attempted to describe design as a process. The notion of process in design dates back to the Roman engineer/architect/writer Vitruvius who described both process and performance aspects of designing. Since the 1940s there has been a variety of attempts to provide formal models of design ranging from prescriptive algorithmic-like descriptions through mathematical model and systems theoretic descriptions to the current paradigm based on the precepts and notions of artificial intelligence. All of these, including the current work, is primarily concerned with treating the process aspects of design.

With apologies to Roger Schank who produced the original title and framework.

Herbert Simon in his 1968 Karl Taylor Compton lectures at MIT coined the phrase 'science of design' to describe that 'body of intellectually tough, analytic, partly formalisable, partly empirical, teachable doctrine about the design process'. Artificial intelligence provides an intellectually attractive paradigm for the exploration and development of design processes. It carries with it its own problems and marries them to the problems of articulating design. This paper brings together ten problems of artificial intelligence in design by relating the problems of artificial intelligence to design and those of design to artificial intelligence.

Problem 1: Representation in Design
A fundamental problem for both artificial intelligence and design remains the one of representation. What is it that a designer knows and how do we get a computer to know it? Even if we are less concerned with what a human designer knows we are still left with the question of what needs to be known to design and how to get a computer to know it and use it.

The early work on representing design knowledge as rules burgeoned into frames and semantic nets. More recently approaches based on conceptual schemas, conceptual graphs and distributed representations have been attempted. Whilst these approaches all add to our ability to represent, there is still a wide gap between what a designer 'knows' when designing and what a computer-based design aid 'knows'.

Problem 2: Design Semantics—Coding and Decoding
Even assuming we know what needs to be known and have a means of representing it we still need ways of interpreting it, i.e. coding it, into the representation. Similarly, we need

ways of decoding an altered representation or the same representation in a different context since one important aspect of design is the shifting context it creates for its own activities. Emergent form is an example of this where a coded representation has to be able to be decoded in a number of different ways in order to understand the various semantics of what has been represented.

Various formalisms have been proposed to deal with design semantics and their transmission. Bond graphs, shape grammars and the like have been used to address the question of emergent form.

Problem 3: Inference in Design
In design, as elsewhere, the content is often much more than has been expressed directly. The intentions are implicit and depend on a commonality of understanding between the sender and the receiver. This includes inferences about what should or could be there but is not expressed explicitly. Much of design inferencing has to do not only with deductive inferences but with abductive inferences which are concerned with what might be rather than what is.

Non-monotonic logics, subsumption, circumscription are just some of the potentially applicable techniques which have been tried.

Problem 4: Combinatorial Explosion in Design
Abductive inferencing brings with it the very real likelihood of combinatorial explosion of potential inferences. As soon as a system deals with what could be then it could go on indefinitely. Context, level of granularity and distance from some starting point assist in controlling combinatorial explosion in addition to standard approaches concerned with formalising constraints on potential inferences.

Problem 5: Indexing in Design
Design occurs in a knowledge-rich and knowledge-intensive environment. However, the more knowledge that is coded into the system the harder it is to find what is useful. Considerable effort has been expended in developing increasingly efficient search techniques. Intelligent systems in design are unlikely to be based around fast search but rather make use of different modes of organisation of memory to aid in the indexing of the knowledge.

Problem 6: Dynamic Modification—Learning in Design
Any notion of design that does not include learning is bound to be deemed unintelligent. In design, unlike in fields which rely on deductive processes, getting the same solution twice for the same problem is considered a failure. Designers learn from doing design and learn from their own and others designs. Understanding this dynamic modification of both the knowledge and the knowledge structures used to represent the knowledge is a fundamental question yet to be adequately answered.

Experimental results from cognitive psychology may provide some clues as to how humans modify their knowledge and their knowledge structures. These could provide an

analogy for computational systems.

Problem 7: Generalisation in Design
The act of designing produces episodes or cases. The ability to generalise from experiences is important if we are to have computer programs which are useful. This is different to learning since what we expect is the ability to draw conclusions from disparate cases or disparate features in a single case.

Problem 8: Situation Recognition in Design
An intriguing issue is how to produce programs which recognise situations at a strategic or semantic level rather than simply at a tactical or syntactic level. Much of the interest in conceptual design lies in the emergence of newly recognised situations, situations which were not produced intentionally but extensionally. The intention–extension distinction plays an important role in design.

Problem 9: Creativity in Design
Design and creativity are often treated synonymously by many people. Clear definitional distinctions have been drawn between routine and non-routine design with the acceptance that not all design is creative. Basic questions remain: are there principles of creativity; are there creative processes; can computers be as creative as humans; and what is needed to be creative?

Problem 10: Evaluation in Design
The evaluation processes in design include not just the evaluation of the technical performance of the designed artefact but also an assessment of its socio-ethical value. This latter aspect currently eludes any formal description. However, for useful intelligent design systems we would expect this issue to be addressed.

Not mentioned explicitly in this list are processes which underlie much of what has been said.

This list is far from exhaustive and represents a research agenda for artificial intelligence in design. Design is one of the most important of human endeavours. Humans are driven to design by their desire for change, experience and improvement. Design is probably the most complex of human intelligent behaviour. Our understanding of ourselves can only be improved by an understanding of ways of dealing with the problems described.