CAPTURING AND MAINTAINING THE CLIENT'S REQUIREMENTS

Case Study

ASSISTING INTERACTIONS IN A DYNAMIC DESIGN PROCESS: A NEW ROLE FOR AN ADAPTIVE DESIGN TOOL

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ABSTRACT

Designing, which is recognized as one of the most complex human endeavours, is critical for the success of any construction project. Design requirements that drive the process are developed inside the design process itself. Designing is an arduous process that requires design expertise and creativity. Designers interact with their design environments in developing the design. They also change the course of developing the design based on these interactions. In order to assist designing in this dynamic process, we need to address the interaction between the tool, the problem it is being used on and the use, in the sense that the tool should be able to learn and construct new concepts from its experiences to facilitate interactions. This paper depicts how a situated agent extends an existing design tool to model interactions, from which the agent learns and constructs its "experiences". Design optimization scenarios will also be discussed to convey the idea proposed.

Keywords: **Designing, Design tool, Situated Agent, Interactions**

1. INTRODUCTION

Designing, the process that produces the structure of an artefact that fulfils the expected function and behaviour, is critical for the success of any construction project. A badly designed facility causes operational failures and incurs high maintenance costs. Design quality is concerned with functionality, which addresses how useful the facility is in achieving its purposes, and build quality, that is the performance of the completed facility (OGC, 2004). Among the critical success factors for achieving design quality, a clear design brief that captures clients' requirements, as well as the related appropriate maintenance during the design stage, have been the focus of many design researches. However, design briefs usually contain abstract terms like "cost effective", "environment concerns", etc., which need to be further re-formalized and developed into detailed design behaviours by the designers. Design requirements that drive the process are built inside the design process itself (Suwa et al., 1999). Designing is a process that requires design expertise and creativity. Designers interact with their design environments in developing the design. They also change the course of developing the design based on these interactions.

In order to assist designing in this dynamic process, we need to be able to address the interaction between the tool, the problem it is being used on and the user, in the sense that the tool should be able to learn and construct new concepts from its experiences to facilitate interactions. However, unlike designers who gain experience while designing, existing design tools keep repeating themselves irrespective of their interactions with the design environment. Such design tools remain unchanged despite their use. Therefore, the work in this paper is motivated by a desire to assist design tasks throughout the dynamic design process with a knowledgeable and personalised design tool. Such a design tool is knowledgeable since it gains experience from its use. It is also personalized because it will change and adapt its behaviour to the interactions in design based on individual use.

This paper depicts how a situated agent extends an existing design tool to model interactions, from which the agent learns and constructs its "experiences" in assisting design.

2. THE NEW ROLE OF THE PROPOSED DESIGN TOOL

Designing can be defined as a means of constructing information in which designers convert clients' functional requirements, regulations and standards, along with their design experiences to design documents. It is a process that is recognized as one of the most complicated of human endeavours. Building design models to understand design process in an attempt to assist this process has long been explored. Recent insights into designing are emerging from the protocol studies of human designers (Gero, 1998). Traditional views of design as static sequential conversion (Figure 1) have been taken over by the notion of "situatedness of designing" that brings forth a situated design model that can be used to develop tools in supporting design. From the findings that have been obtained from protocol studies, designers not only synthesise solutions that satisfy initially given requirements, but also invent design issues or requirements that capture important aspects of the given problem (Suwa et al., 1999). For this reason, design requirements are more interactive and situated, in the sense that the designer's interpretations of the requirements change according to what we summarize as "where you are when you do what you do matters".

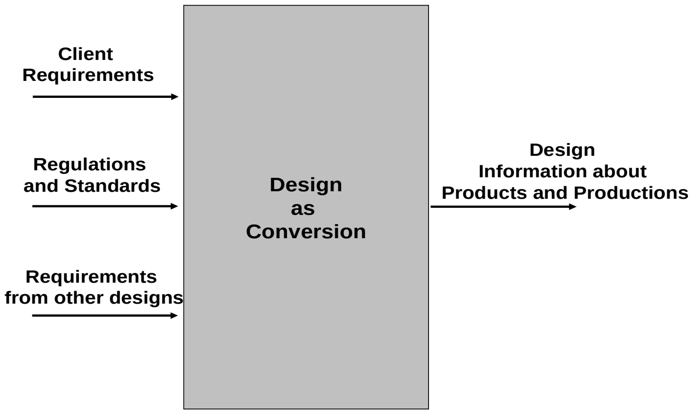

Figure 1. A sequential conversion view of design (adapted from Fabricio et al., (1999)).

Therefore, a new approach is needed to address interactions throughout this dynamic design process, such that the interaction between the designer and the tool can be captured. However, under the traditional paradigm, design tools have been built based on the notion that the tool is unchanged by its use (Gero, 2003). These tools communicate with users through "direct manipulation" in which tools as passive entities merely wait and respond to specific, highly detailed instructions (Green et al., 1997). Using these tools in design cannot meet the changing needs of the designers and the design. Thus, our approach is to develop a situated agent which enables a design tool to learn the interactions during design, and to subsequently use the constructed concepts to facilitate interactions between the designer and the design environment. Figure 2 illustrates this new design tool and demonstrates how this tool learns from events performed by the designer. The incorporation of a situated agent which can sense and affect its environment enables the design tool to learn the ongoing interactions in the design. The agent senses the activities of the designer and then constructs interaction concepts. Learning refers to the concept formation process in which the agent's experiences are reinterpreted, re-structured and reinforced. The process includes perceptual categorizing, conceptualization and reflective reasoning of the current design interactions that is a combination of the interpretations of the external and internal environment within which it is situated.

The suggestions produced by the agent contain information about current design situations that snapshots the sets of entities and relationships involved in designing at a given time stamp. These concepts are formed based on the agent's experiential response to the regularities of the observed design tasks, which can be further served as new suggestions to the designer in guiding their design activities.

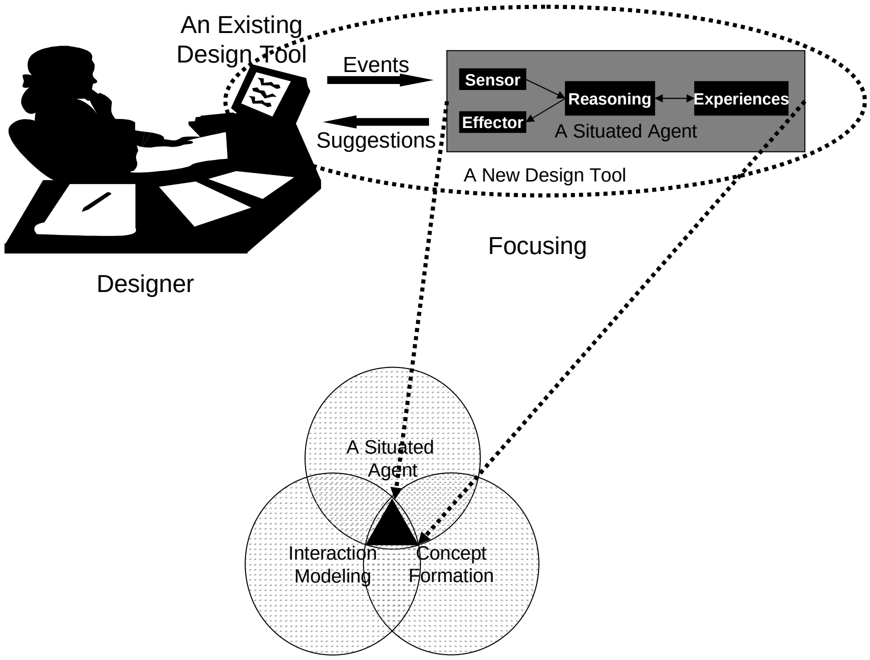

Figure 2. A new design tool and its internal learning mechanisms

3. A FRAMEWORK OF DESIGN TOOLS THAT ADAPT TO THEIR USES

We describe a situated agent that extends an existing design tool to model interactions, from which the agent is able to develop "experiences". Adaptation, as the agent's ability to accommodate incremental changes in the environment, enables the design tool to learn from and cope with the interactions in the dynamic design process. As shown in Figure 2, the agent learns from its interaction with the design environment, which includes an existing design tool, the designers, and their activities in forming new concepts which further affect interactions in design. And agent's experiences bias this concept formation process. The constructive memory model (Gero, 1999), which serves as a meta-level learning mechanism in controlling base level machine learning approaches, also lets the agent learn new situations that will later be grounded in the agent's experiences by its use.

3.1 A SITUATED AGENT ARCHIETECTURE

The agent learns by constructing "experiences" from its interactions with the environments based on its internal representation processes, memory construction and grounding mechanism. The design tool relies on the agent's situated cognition and changes its behaviours which are embodied as "reflexive", "reactive" and "reflective" behaviour (Maher and Gero, 2002) to adapt to its use. Here adaptation results from the totality of the coordination of these behaviours within the process of memory construction and grounding.

The internal representation processes consist of sensation, perception, conception, hypothesizing, expectation generation and modification. Each couples with one another in synthesizing data driven from environment with expectation-driven experiences in order to form constructed memory, Figure 3.

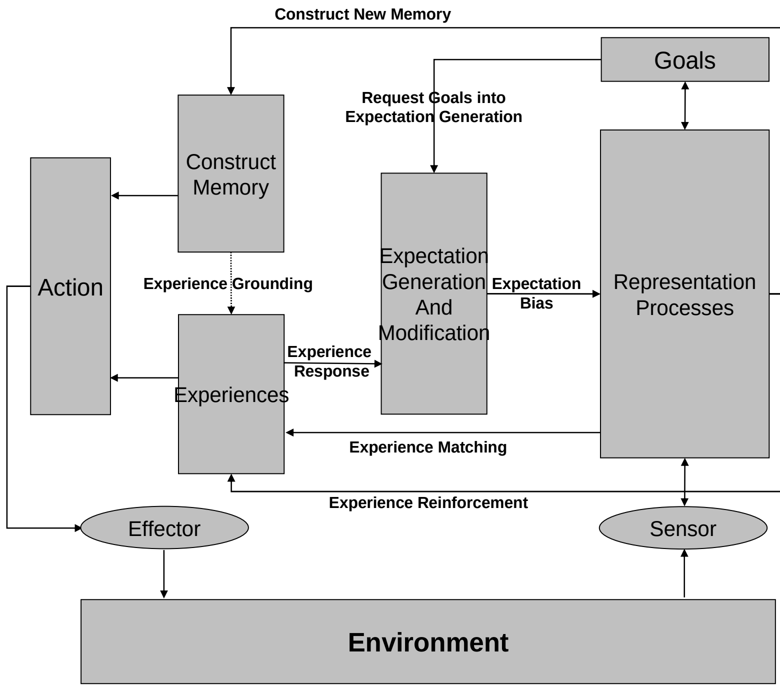

Figure 3. The architecture of a situated agent (adapted from Gero & Peng (2004)).

Sensation is the process of generating sensory data from outside stimuli for further processing. Perception is the process of generating percepts from sequencing and coupling sensory data. Perception also structures these adapted sensory data into sequence or simultaneous chunks (percepts) based on past sequences, coupled categorizations (perceptual experiences) and activated abstractions of percepts (concepts). Conception is the process of categorizing perceptual sequences and chunks in order to form concepts. Concepts are abstractions of experience that confer a predictive ability for new situations (Rosenstein and Cohen 1998; Smith and Gero, 2000).

Expectation generation and modification processes play a crucial role in constructing memory which matches past experiences. Expectation, which is related to agent's view about possible consequences of certain actions, affects its decision making. The hypothesizing process analyses the possible causality of expectation failures and hypothesizes possible solutions. A situated agent reinterprets the design environment based on expectations which are regenerated from matching refocused concepts with current situation.

Agent's actions are embodied as design tool's behaviours which result from coordination of internal representation processes. It is through action that the agent's constructed memory is connected with the environment such that feedback from the environment can serve as cues for the modification of agent's behaviours.

The sensor is the unit by which an agent receives and gathers stimuli from environments. An agent obtains access to the environment through sensors and affects the environment via effectors. An effector is the means by which the agent brings changes to the environment through its actions.

3.2 THE DESIGN TOOL'S ADAPTIVE BEHAVIOUR

A design tool's adaptive behaviours are embodied as reflexive, reactive and reflective behaviour in response to changing situations occurring in the interactions. We discuss adaptive behaviour, in which the design tool manifests as agent's ability to change tool's behaviours to achieve goals based on the concepts formed from the agent's situated representation mechanisms and a constructive memory system.

An agent responds reflexively to environment stimuli based solely on its experiences without reasoning when its experiential response to current sensed data is sufficiently strong to affect action directly. Agent reacts to environment stimuli, when the experiential response to currently sensed and perceived data is sufficiently strong, such that the perceptual experiences in terms of habitual sequences or coupled information can directly affect actions. In its reflective behaviour, the agent coordinates all the representation processes in providing an ongoing awareness about the situation. It is the agent's reflective behaviour that enables design concepts to be constructed. These concepts represent the agent's belief about the possible incoming events and the consequences of the resulting actions.

4. A DESIGN SCENARIO

In this section, a simplified spatial layout problem, treated as a design optimization scenario is discussed to show how this adaptive design tool can be used to improve the designer's interaction. The design objective is to find an optimal layout within certain design constraints. The clients' requirements in this problem are described as "minimize construction cost" and "maximize usage area". The floor layout is described in Figure 4.

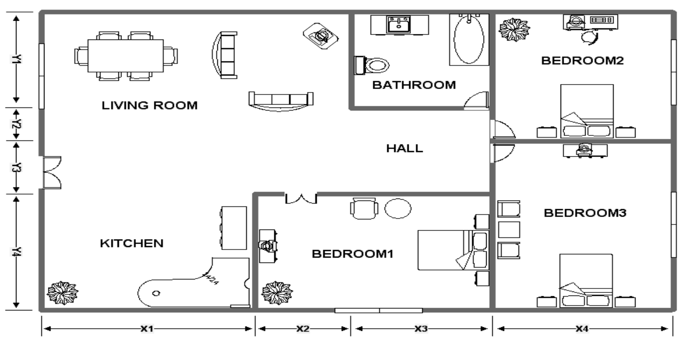

Figure 4. The floor plan of an apartment used for design optimization.

A scenario is illustrated in Figure 5, designers formulate the clients' requirements into objective functions and then apply a suitable optimization algorithm to the design problem. They not only choose optimizers based on their own experience, but also explore new approaches in a trial and error manner. In this way, they will eventually reach a solution during the interactions with the design environment.

The solution is only satisfactory to the designer but may not the optimal. How can a design tool improve its behaviour based on its use by the designer?

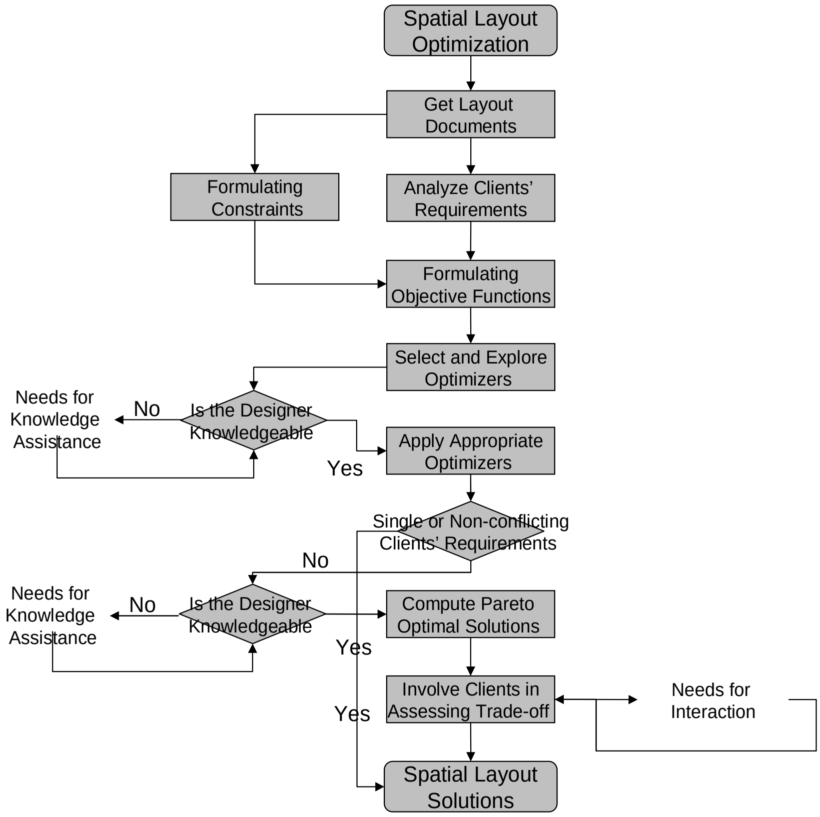

Figure 5. Needs for design knowledge supports and interactions for a typical design optimization problem.

A situated agent can be involved in constructing concepts resulting from the interactions between the agent and its environment that include the designer and the design. Sequences of events performed by the designer are further sensed and perceived by the agent. These environmental variables then activate the agent's associated sensory experiences which are structured as a portion of an Interactive Activation and Competition (IAC) neural network (McClelland 1981; 1995). An IAC neural network applies an activation and competition mechanism to a set of instance nodes which are further linked to groups of property nodes. The agent's sensory, perceptual and conceptual experiences can be represented as different layers of an IAC network. In constructing a concept for the current situation, environment variables undergo different levels of processing (Liew & Gero, 2002) through the agent's internal representation processes and experiences.

Thus, an environment variable at time stamp "Ev(t+n) = {… "click on objective function text field", "K", "X", "^", "2", "+" … "submit objective function" … "select optimization algorithms", "click on QP algorithm", "K", "X", "^", "2", "+" …"submit" … "Algorithm" … "DP" … "K", "X", "^", "2", "+" … "submit" … "Algorithm" …"GE"…}" can be constructed as a concept that can be used as suggestions for the designer to select suitable optimizers, Figure 6.

Another problem arises when the clients' requirements conflict with each other. Then it is necessary to involve the clients in the design process to negotiate a trade-off solution. The objectives of "lowest construction cost" and "maximum usage area" conflict with each other in this design scenario. With the Pareto optimal set generated, the agent can construct a design concept in terms of a two-dimensional plot which represents each solution in clients' requirements space, Figure 7. Some heuristic rules can also be developed to give a trade-off suggestion to the designer and the clients involved.

New Concept

- **Focused Concept:**
  P1(x^2) → GE
  G2 is the modified active goal based on performance of use
- **Hypothesis:**
  1: X^2 → QP 70%
  2: X^2 → DP 60%
  3: X^2 → GE 50%
  On frequency of use
- **Hypothesis:**
  1: X^2 → GE 70%
  2: X^2 → DP 60%
  3: X^2 → QP 50%
  On performance of use
- **Hypothesis:**
  1: X^2 → GE 70%
  2: X^2 → DP 60%
  3: X^2 → QP 50%
  On Trade-off

Figure 6. An example of possible concepts constructed by the agent.

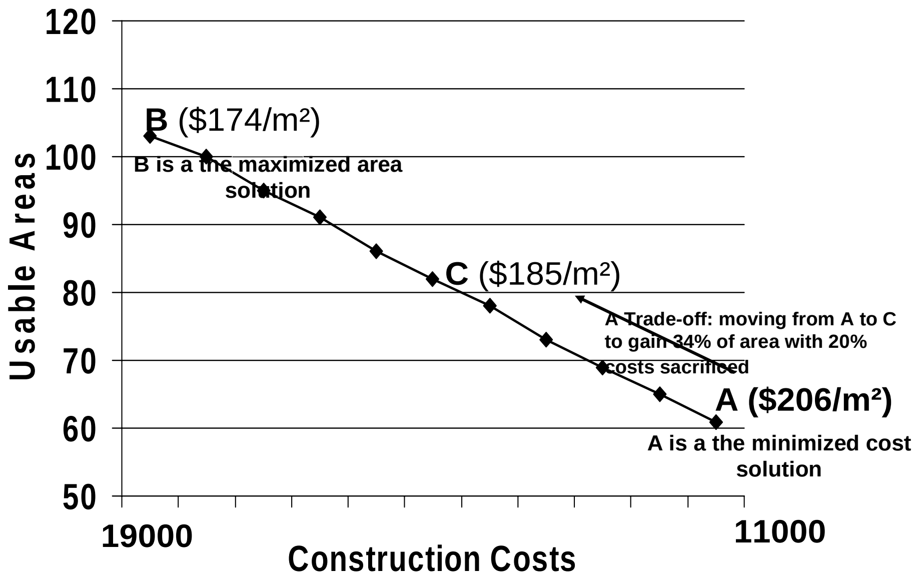

Figure 7. An example of design concepts for solving conflicting clients' requirements (created from the data adapted from Balachandran (1988)).

5. DISCUSSION

This paper describes a new role for a design tool to assist the interactions during which the client's requirements can be further developed by designers in a dynamic design process. These client's requirements are formulated into design goals. A situated agent learns and constructs concepts that represent designer interactions with the tools in which the tools used in the design process are augmented to account for the experiences that have been gained in using them.

Within this knowledge demanding design process, the proposed design tool also plays an important role in supporting the design with the knowledge it learnt from the agent's interaction with the design environment. The knowledge constructed during designing is further grounded as experience which subsequently biases the agent's concept formation in a later time frame. Designers are connected to the agent's knowledge which can guide the interactions in design. However, this is not to suggest that the tool will be developed into a knowledge database that is widely regarded as not dynamic in addressing the interactions in the design. Even a tool that learns about a particular problem may not be applicable in another domain because the problems lack similarities (Gero, 1996). To solve this challenging problem, an important notion is that the tool is being reused instead of the knowledge which is constructed during the usage of the tool. We may need to build specialised agent for particular tasks or functions of design tools.

As a common ground that can be shared by the design teams even the clients, this adaptive design tool is able to be personalised so that different user groups have their own interactions. This will be one of the future milestones yet to be delivered.

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