Externalising The Internal: Collaborative Design Through Dynamic Problem Visualisation

Mark Perry[*] *and Peter Thomas*[†]

[*]Department of Computer Science
Brunel University
Uxbridge, Middlesex, UB8 3PH
United Kingdom
Tel: (+44) 1895 274000 x2136
email: Mark.Perry@brunel.ac.uk

[†]Centre for Personal Info. Management
Computer Studies and Mathematics
University of the West of England
Coldharbour Lane, Bristol, BS16 1QY UK
Tel: (+44) 117 965 6261 x3154
email: Peter.Thomas@csm.uwe.ac.uk

Abstract

In collaborative system design, problems can arise through the differing aims, plans and goals that participants hold. Simulation models can be used as visual representations acting as dynamic 'blackboard' models of design problems. These representations permit problem understanding through the externalisation of individual stakeholder mental models, making them available to all involved. Informed negotiation can then ensue of the design ideas and iterative redesign can proceed until a final decision can be agreed upon. Understanding the role that representations play in sharing designers' mental models suggests several changes to the design of the simulation modelling environment.

Keywords

Mental models, collaborative design, co-operation, simulation modelling, visualisation, representations.

1 Introduction

Collaborative system design poses a number of problems, not only those encountered by individual designers in the collaborative process, but also co-ordination problems that arise from multiple agendas and understandings of a design problem. Providing tools to support the collaboration of the various 'stakeholders' in design is therefore an important goal which has already been the subject of research in CSCW and other disciplines (e.g. Boland et al, 1992; MacLean, Young & Moran, 1989; Muller, 1992).

Designing complex systems of any kind places high cognitive demands on the agents. Necessarily, various methods of external storage of intermediate plans, results and processes, such as diagrammatic representations, are often used. However, when a process is dynamic, these static representations are inadequate. Texts are often used to represent information that changes over time, but again, when problems are complex and dynamic, traditional methods of representation do not work well. Confusion can occur, resulting in poor solutions.

Where there are several (and often equally ranked) stakeholders these problems are compounded: with multiple agents, perceptions of the problem differ, as do the ways that they propose to solve them. This is made more complex because agents are often unable to unambiguously make their ideas explicit.

2 Computer Implemented Simulation Models

One method which enables stakeholders to co-ordinate their activities in the solution of large-scale design problems is a *computer implemented simulation model* (CISM). As an artifact supporting design, a CISM is a dynamic 'blackboard' which functions as a medium for communicating problem understandings between various stakeholders. It involves the creation of a logical, conceptual model of a system-under-design (Paul, 1992 - e.g. a steelworks, or a hospital waiting room), initially diagramatically and then converted into a dynamic, computer based representation.

In current practice, an analyst performs the modelling process. The computational model allows the user to interact with the logical model of a hypothetical system-under-construction. The user interface to a CISM thus represents the relationships between interactive entities in the model. Although crude, these dynamic, visual representations enable users to understand the developing logical model of the system.

Examples of CISMs performing these functions have been documented. Unfortunately, these reports are more hearsay than analysis. One such CISM is that of a port simulation (El Sheikh, Paul, Harding & Balmer, 1987) where the solution to the problem was known before the simulation was made: its function was to allow discussion amongst the stakeholders to facilitate agreement. Another example is that of CLINSIM (Kuljis & Paul, 1994) where the purpose of the simulation was to form a vehicle for debate amongst participants involved in managing out-patient clinics: through (visually) observing different strategies, both doctors and managers could understand and collaborate on improving patient waiting times.

In work carried out in the Centre for Applied Simulation Modelling at Brunel University we are interested both in the design of more effective simulation modelling tools, but also in the ways in which simulation models function in support of the design process we have described. We have therefore been studying the ways in which simulation models provide various kinds of support for the collaborative design process.

In particular we are conscious that CISM evolved as a means of understanding systems and improving their performance. As a consequence, a methodology to represent simulation models has developed to take account of *technological*, rather than *user-oriented issues*, so we now have simulation systems with little motivation other than that of 'simulating better'.

We have therefore been looking at the human factors of the simulation modelling process with a view to understanding how simulation models function in the collaborative design process with a particular interest in the role of the user interface in the simulation model.

3 CISM and Group Problem Understanding

CISMs allow a number of processes to occur that are important in group problem understanding:

1. CISM provides a means of representing exactly how specifications will be implemented in the development of a real world system, allowing the stakeholders a means of visualising how the end product will be expected to function.

2. Non-expert designers (as many stakeholders are in their non-specialist areas) need a clearly recognisable representation of their and other stakeholders' mental models to allow 'perspective sharing'. CISM provides a medium through which designers can communicate, to express their mental models more clearly than other means of technical communication allow in the particular design situation.

3. The CISM environment permits communication and allows the transmission of mental models that would otherwise only be transferred implicitly, available to other stakeholders through more ambiguous communicative channels.

4. Visualisation of the problem space supports communication: agents that can understand what other agents are trying to communicate will be able to negotiate about designs in an informed and unambiguous manner.

5. By moving internally held designs into 'knowledge in the world', information becomes available to all of the stakeholders involved in design.

6. The CISM aids collective problem solving by giving the stakeholders a common representation of the problem space.

7. CISM forces designs to be elaborated on and to become more fully formed.

8. A representation in the world, separate from individual designers, operating as a 'group memory' means that there is a unified space where a design resides.

9. Different people can work on a problem without constantly reviewing its' state. CISM allows an informed process of negotiation based on the merits of competing or opposing plans.

10. CISM allows the designers to specify the ways that their 'wishes' could be brought together to solve the problems envisaged in an abstract way: construction of the problem space.

Integration of ideas into a final design model is not achieved by simple summation of all stakeholders' perspectives to form a general model, but involves compromise, found through dialogue, in which conflicts are recognised and discussed. Conversational dialogue is not capable of carrying the large amount of information necessary for dynamic, complex design. Simulation modelling offers a simple and efficient method of capturing this material. Some of these are functions of other representational systems, but CISMs allow planning of a system that changes over time because they are dynamic, rather than static.

4 The Human Factors of CISM

CISM is useful in design because it not only deals with 'technical' issues, but also supports 'real world' issues - those involving stakeholder disputes and conflicts.

CISM interpretation is crucial to the way that stakeholders are capable of understanding dynamic systems. Clarity of matching the model to the processes, that we as humans are good at processing (real objects in a real world) from the representations that computers and statisticians are good at manipulating (formal descriptions in terms of mathematical equations), is vital in creating an environment that people from all backgrounds are able to participate in. Thus, simulation modelling can be clearly seen to 're-represent' information in a simple and informative way.

Our studies suggest that through stakeholders communicating their ideas with other agents, the design problem is not so much solved, as resolved: the initial problem in collaborative design is deciding what the problem is (this concept has been considered in design rationale [MacLean, Young & Moran, 1989], which deals with efficient methods of carving up the design space). Early on in design, the problem is not of moving through the problem space, a set of distinct steps, but of asking what the nature of the problem is (analogous to moving from an ill-structured [Simon, 1973] to a well structured problem space - over a distributed cognitive system [Norman, 1993]). Through iterative re-representation, a solution, meeting most of the specifications held by the stakeholders can be brokered. When stakeholders do not understand the reason for a particular design, or disagree on it, they can go to the originator of the design (or more likely the analyst) and argue their case with a knowledge of what that designer meant and the context into which it was placed. This communication is simplified because contextual information resides in the visual information onscreen. Communication is only of *why* something is as it is, and does not need to include additional explanative information.

As suggested above, little work has been done into the human factors of simulation modelling. Studying simulations in the real world should lead development rather than expecting technological advances to provide solutions. As a medium for communication, the implementation of simulation models needs reappraisal. Initial conclusions in a pilot study suggest that CISMs are used as a collaborative information resource. These findings suggest three main enhancements to the modelling process:

a) Modifying the interface to allow simple manipulations of the CISM by the stakeholders themselves so that they can test their mental models against it. If this is not possible, for reasons of model complexity, then the CISM should be quick to modify by an analyst.

b) Generating a clearer, more informative and easier to interpret visual representations of the developing CISM to improve group conceptualisation, thus developing good mental models of both the problem and system-under-consideration.

c) Stakeholders need to be intimately involved in the process of CISM construction so that they can understand *why* the design develops in a particular direction.

To understand the factors involved in the interpretation of design ideas and how stakeholders understand the developing design, we have also looked at the problem in terms of the perspective of 'mental models' from work in the psychology of HCI. Mental models are representations of how systems work, their components, relations, internal processes and causal attributions (Carroll & Olson, 1988). Initially, mental models embody implicit assumptions which are later made explicit by discovering where the internal consistency, correspondence and robustness of the original model fails. This process of modification is important to our understanding of communication, because a common viewpoint allows further sharing and dissemination of information.

CISMs and mental models are both representations of system processes and are both modifiable to capture the relevant aspects of a problem. Of course, mental models are not easily examined either by their 'owner' or by others. On the other hand, CISMs are held externally and, with a well designed interface, fully available to inspection by people other than their creator. Each representation therefore permits a different pattern of use, specifically, one facilitates a group understanding and the other is central to individual cognition.

Paul & Thomas (1994) claim that the key to successful simulation modelling is the integration of different user models of the system under design. They suggest that CISM communicates 'problem understandings' amongst participants by constantly reformulating the problem to get a common understanding of the processes involved: developing a CISM may be more useful than the model itself.

5 Conclusion

Better tools are needed to support designers. Designers working alone require tools that aid individual performance. Collaborating stakeholders require a different form of support, co-ordinating their efforts and resolving conflicts. This can only occur if stakeholders can recognise and understand the needs and wants of others. In a complex, dynamic design environment, CISM can offer this help. Through improving the CISM interface we can enhance problem visualisation and further support group work.

References

R.J. Boland, A.K. Maheshwari, D. Te'eni, D.G. Schwartz & R.V. Ramkrishnan (1992). Sharing perspectives in distributed decision making. *CSCW'92 Proceedings*. ACM Press: 303-313.

J.M. Carroll & J.R. Olson (1988). Mental models in human-computer interaction. In Helander (Ed.) *Handbook of Human Computer Interaction.* Amsterdam: North-Holland.

A.A.R. El Sheikh, R.J. Paul, A.S. Harding & D.W. Balmer (1987). A microcomputer based simulation study of a port. *Journal of the Operational Research Society, 38(8)*: 673-681.

J. Kuljis, & R.J. Paul, (1994). Outpatient clinic waiting times: a visual simulation approach revisited. Presented at the *3rd Medical Informatics Conference*. Hong Kong.

A. MacLean, R.M. Young & T.P. Moran (1989). Design Rationale: the argument behind the artefact. *CHI'89 Proceedings*. ACM Press: 247-252.

M.J. Muller (1992). Retrospective on a year of participatory design using the PICTIVE technique. *CHI'92 Proceedings.* ACM Press: 455-462.

D.A. Norman (1993). *Things that make us smart.* Reading, MA: Addison-Wesley.

R.J. Paul (1992). The Computer Aided Simulation Environment: An Overview. *Proceedings of the Winter Simulation Conference*, ACM Press: 737-746.

R.J. Paul & P.J. Thomas (1994). Computer-based simulation models for problem-solving: communicating problem understandings. *The Arachnet Electronic Journal of Virtual Culture, 2(2).* ISSN 1068-5723.

H.A. Simon (1973). The structure of ill-structured problems. *Artificial Intelligence, 4:* 181-200.