Supporting the Construction of Qualitative Knowledge models
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Summary

This thesis is about using modelling as a means for learning. It uses the idea that the inherent explicitness of a model and the manipulation of knowledge prevalent during a modelling process stimulates the apprehension of scientific reasoning skills. Furthermore, it proposes the use of a qualitative ontology as a means for developing conceptual knowledge by learners.

Chapter 1 discusses qualitative modelling and gives an overview of the most significant achievements in the field. In addition, the important topics of model content visualisation and support in articulate knowledge modelling are enumerated. This Chapter concludes with a summary of the research goals of the thesis.

Chapter 2 discusses the design of model building environments. The discussion revolves mainly around three key issues; firstly, expressing the tasks involved in modelling a system and its behaviour by making use of a qualitative vocabulary, secondly, defining means for visualising the various model ingredients and, finally, specifying effective ways of interacting with those ingredients. Some important conclusions are drawn from this discussion. Next, a rational task analysis is used to identify a set of distinct and manageable tasks for building qualitative simulation models. Our analysis suggests that a canonical set of seven modelling activities cover the complete range of activities needed for qualitative model-building. Another important topic treated in this chapter is the visualisation of the inner details of a model. For that purpose we define a series of general principles. Based on these, two alternative visual organisations of model ingredients on the screen are presented. One approach centres around the unique role of the entities, whereas the other considers all model ingredients to be equally important. It is also mentioned, that a concrete implementation of a model building environment will eventually involve the concepts of builders, tools, graphs, vertices, and arcs. The conceptual foundation of this framework is detailed in this chapter.

Chapter 3 presents a field experiment using the qualitative model-building environment called HOMER. The purpose of this experiment was to validate the task analysis presented in the preceding chapter. To our general satisfaction, all subjects smoothly followed the implicit task execution sequence proposed by the environment. An exception occurred with the creation of quantity spaces; possible explanations for this are discussed.

Another interesting result was that most subjects felt the need to make drawings of their models in order to get a better understanding. This suggested that a future implementation of the building environment should support a model sketching task. Also, subjects were often found constructing a full causal explanation of the behaviour of their system which suggested that a causal 'model-view' should also be supported by a future implementation. In order to gather a complete list of usability problems, the heuristic evaluation method was used. We were especially interested in assessing the problems concerning
the user interface. A number of problems related to the process of building qualitative models were evident; they were categorised into four main classes: scoping, structuring, representing the model, and understanding the model-building concepts. We were able to conclude that HOMER is already a tool which enables users to create basic qualitative models. However, constructing models is a difficult task and the provision of additional support is needed in order to have subjects effectively use qualitative modelling tools such as HOMER.

Chapter 4 discusses ideas on how to add support to an interactive learning environment. Based on a literature study of software systems that are somehow related to the work presented in this thesis, we try to identify the best traits of existing support systems in learning environments, so as to be able to include them in a future version of our model building tool. We conclude that domain independence necessarily implies a more demanding support system; that since qualitative modelling is not part of standard curricula, support regarding the Qualitative Reasoning ontology must be included; that simulation results themselves are a form of feedback and that therefore it is essential that model-building and analysis of simulation results occur in one and the same environment; and finally that pedagogical agents represent a new learning paradigm and we therefore propose a set of agents featuring personification and modularity.

Chapter 5 addresses the design of MOBUM, a prototype model-building environment for constructing qualitative models. Its design is based on the experimental evaluation of HOMER described in Chapter 3, during which a series of problems regarding user interaction and support were detected. As such, MOBUM offers a more consistent and flexible user interaction. It offers the ability to run a simulation and inspect its results in one and the same environment. User feedback has been significantly improved, mainly by means of an agent-based engine which offers support at various levels, ranging from offering help on conceptual knowledge to giving advice about the completeness and correctness of ones model at every stage of the model-building process and suggesting useful actions to the modeller. Furthermore, MOBUM has been equipped with the so-needed abstraction tools in form of the SWAN SketchPad, a drawing tool for the purpose of making quick and unconstrained drawings of one's ideas, and the Causal Model Builder, which allows a learner to formalise and specify a causal model without being concerned with other aspects. Chapter 5 also summarises the overall design methodology used for the implementation of MOBUM. Special emphasis is given to the interactive cycle involving Design, Prototype Implementation, and Evaluation.

Chapter 6 presents a field study using the newly implemented prototype system MOBUM. The main conclusions drawn from this study are the following. Firstly, we conclude that model-building support is an essential feature of any learning-by-doing environment. The support system should only allow the construction of syntactically correct models; it should possess knowledge about the model construction process and the actual status of the model at every stage of the modelling sequence; it should provide help beyond the syntactic level; and be useful to both novice and expert users. Our second main conclusion regarding the research described in this thesis concerned the design of the user interface. An experiment was undertaken with the purpose of evaluating the impressions of the users concerning the user interface in general and also when compared to the user
interface of HOMER. The overall conclusion is that the user interface of MOBUM was clearly more appreciated, thus validating the model visualisation principles described in Chapter 2. Chapter 6 concludes with a series of suggestions for further improvements in future implementations of the qualitative model-building tool.

Chapter 7 concludes this thesis. It summarises the situation at the beginning of this research project and discusses its main achievements. The thesis is closed with a number of suggestions on possible future developments and further improvements.