Chapter 12
Using Drawings in Knowledge Modeling and Simulation for Science Teaching

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Abstract. Modeling knowledge in simulation-based inquiry learning requires a model of the domain that is executable, as well as a model of the learners’ knowledge about the domain. An intermediate level is formed by models of the domain that are created by students as is done in modeling environments. An approach is presented for generating student created models from drawings. This approach requires drawing segmentation, shape recognition and model generation, which is done based on density-based clustering, elementary shape recognition combined with a shape ontology and model fragment composition respectively. The final result is an executable model that can be used to generate simulation outcomes based on learners’ conceptions. The role of such a system is discussed, especially with respect to the diagnosis of misconceptions and the generation of tutoring interventions based on confronting learners with the consequences of their conceptions.

12.1 Introduction

In inquiry learning with the help of simulations and modeling, knowledge is modeled at three levels. First there is the level of the authored simulation (van Joolingen and de Jong 2003) in the form of an executable model that drives the simulation as a main resource for inquiry. The second level is that of models created by students, in the form of concept maps, system dynamics models or stated hypotheses and conclusions (Novak 1998; Penner 2001; Schwarz et al. 2007; Wilensky and Reisman 2006; Wilensky and Resnick 1999). The third level is that of models the system makes of learners’ knowledge. Although these levels of knowledge modeling serve different purposes and therefore need to satisfy different requirements, they also have much in common as they rely on similar representations representing relations between variables in the domain. In many cases representations at all three levels need to be simulated. At the level of the simulation this is obvious. It has also been known that for the level of learner created models a simulation based on a learner generated model can have a beneficial effect on the learning process (Alessi 2000; Bliss 1994; Ergazaki et al. 2007;
Feurzeig and Roberts 1999; Sins et al. 2005). At the level of the model of learners’ knowledge simulation of a model can help to identify conflicts between learners’ hypotheses and predictions on one side and the model that the learner is studying on the other. Differences in models generate difference in simulation results which are opportunities to confront and discuss with learners in the knowledge building process.

In the current chapter we focus on the middle level, the representation of models by learners. As noted, learners can use many different kinds of representation to express their own models. Some of those representations, such as system dynamics models allow to be simulated right away, but have the drawback of being quite formal and requiring prior knowledge of the variables and relations in the domain, as well as knowledge about the notation and syntax of system dynamics. Other representations such as concept maps can be helpful, but cannot be simulated. Moreover, concept maps are good for building conceptual structures, but they are not really geared towards representing computational operations. Finally, concept maps also impose a kind of formalism on the kind of representations to use by students. Learning environments such as Cool Modes (Bollen et al. 2002) try to combine different visual languages like system dynamics, UML diagrams, freehand drawing etc. in one workspace, but these languages rarely interoperate, and especially freehand-drawings are only integrated on a visual level.

We try to address the problem for representing learners’ models by letting learners make drawings representing their understanding of the domain. Using freehand drawings and sketches provides the most representational freedom, but it usually lacks any form of operational semantics. Recent sketch recognition systems try to include this kind of modeling support to drawings, e.g., for drawing logic diagrams (Alvarado and Lazzareschi 2007) or for recognizing mathematical expressions (LaViola and Zeleznik 2004), but they also inherit the limitations and restriction from the domain they are trying to support and from the language they try to recognize.

The approach presented in this paper brings together representational freedom and operational semantics. This approach allows learners to externalize and visualize their ideas on a phenomenon by using freehand drawings, which can be used to intelligently support the creation of a quantitative model by means of segmentation support to recognize coherent components in a drawing, sketch recognition for detecting basic shapes (e.g. arrows, links between components) and labeling to provide a means to the user to identify and tag relevant characteristics and properties of sketch components.

12.2 Modeling with Inaccurate Drawings

In this section we will describe the main properties of the system to generate models from drawings. We start with describing the context and rationale, and proceed with describing the necessary steps to move from drawing to model. In subsequent sections, the first results of implementing the approach will be presented.

When creating a model, many people, including experts, start by making a drawing that is a more or less schematic representation of the system that is being modeled. Drawings help identifying the main components that need to be included