Basic Framework for Learning by Constructing Cognitive Models Based on Problem-Solving Processes

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Abstract: Construction of models is promising as a learning activity. However, it can be a difficult activity which imposes heavy load on learners because it requires eminent skills. This study proposes a basic framework for learning by constructing models of a production system in the domain of cognitive science. In this framework, a model abstractly describing human problem-solving processes and its computer model implemented on the production system is prepared by an instructor in advance. A learner is given the abstract model and problem-solving processes produced by executing the implementation model, and then engaged in instantiating the abstract model into an implementation model. This activity is expected to deepen learner understanding of cognitive processes embedded in the abstract model. We implemented a support system for the framework.

Keywords: Learning by construction, cognitive model, production system, problem solving

1. Introduction

Science in recent decades has used two approaches to understand the natures of targets: an analytical approach through observation of targets, and a constructive approach through construction and simulation of target models. For example, within cognitive science research, running computational models has been adopted in understanding human mind in addition to empirical studies of human behaviors (Schunn, Crowley and Okada, 1998).

Construction is also promising as a learning activity. However, it can be a difficult activity which imposes heavy load on learners because it requires eminent skills such as implementation of a model with a programming language. Therefore, several studies addressed support for learning by constructing models (e.g., Basu, Dukeman, Kinnebrew, Biswas and Sengupta, 2014; Hirashima, Imai, Horiguchi and Toumoto, 2009). Support by the studies allow learners to construct and simulate models by designing models abstractly describing the attributes or behaviors of targets. Instantiation of the models into computer-executable models is left to support systems. Here, the former models of abstract description of targets are referred to as *abstract models*, and the latter as *implementation models*.

Basically, abstract models are critical in learning by construction because they are externalized products in understanding of targets. On the other hand, implementation of models also plays a critical role in deepening understanding as demonstrated in history of cognitive science. One of the central keys in learning by construction is to receive feedback from actual or virtual worlds through instantiation of abstract models into implementation models (Nakashima, 2008). Moreover, it is difficult to adapt learning by design of abstract models described with objects, agents and their attributes to some domains. Mental processes in problem solving by a person, for example, are not properly represented with interactions of objects and agents. Therefore, learning of such targets must require a different approach.

This study proposes a basic framework for learning by constructing models in the domain of cognitive science. This framework provides learners an abstract model and allows them to experience instantiate it into an implementation model with moderate load.

2. A Framework for Learning by Constructing Cognitive Models

This study adopts human problem-solving processes as learning targets and a production system as an architecture of implementation models. Production systems are one representative architecture in cognitive science. We proposes a framework for learning of cognitive processes by constructing production models.

The overview of this framework is illustrated in Figure 1. In this framework, an abstract model and its implementation model is prepared by an instructor in advance. A learner is given the abstract model and problem-solving processes produced by executing the implementation model. He or she is then engaged in instantiating it into an implementation model by himself/herself with production rules according to the processes. Our previous study confirmed that such an activity to reproduce a target based on its construction processes facilitates understanding of the target structure (Kojima, Miwa and Matsui, 2013). Thus, this activity is expected to deepen learner understanding of cognitive processes embedded in the abstract model (e.g., sophisticating a mental model of learners about a phenomenon the abstract model represents).

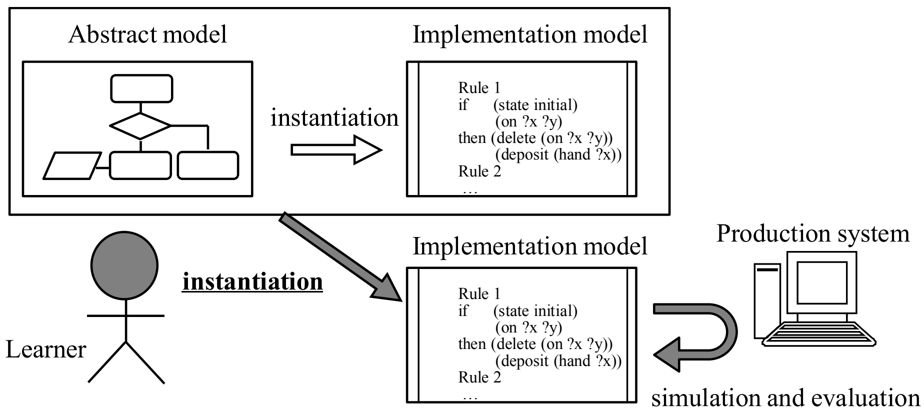

Figure 1. Framework for learning by constructing cognitive models

3. A Support System for the Framework

We implemented a support system for the framework described in the previous section. It uses DoCoPro (Nakaike, Miwa, Morita and Terai, 2009), a production system designed for learning by constructing models by novice learners, as the architecture of implantation models. Before the system is given to learners, an instructor implements a cognitive model for an abstract model of human problem solving on DoCoPro. The system executes the model and extracts its processes. It then creates information indicating steps involved in the processes of model execution. This information includes explanation of a production rule fired and two states before/after the rule firing for each step of the processes. Figure 2 illustrates an example of structure of the information.

A learner is then given the abstract model and instantiates it with the support system shown in Figure 3. As the left side of the figure indicates, the system provides information of each step in processes from the implemented model by the instructor. For every step of the model processes, the learner composes a production rule which can change the before-state to the after-state with the editor of the right side. The learner can check his/her rule on each step through comparison between the after-state and the result from firing the rule. Construction of the implementation model is completed through composition of rules for all steps. Although learners cannot experience design of problem representation in this framework, it enables the learners who are not familiar with coding skill to experience instantiation of an abstract model and receiving of feedback from the instantiation. We are now working on an empirical study to test the effectiveness of learning by constructing a cognitive model with the system.

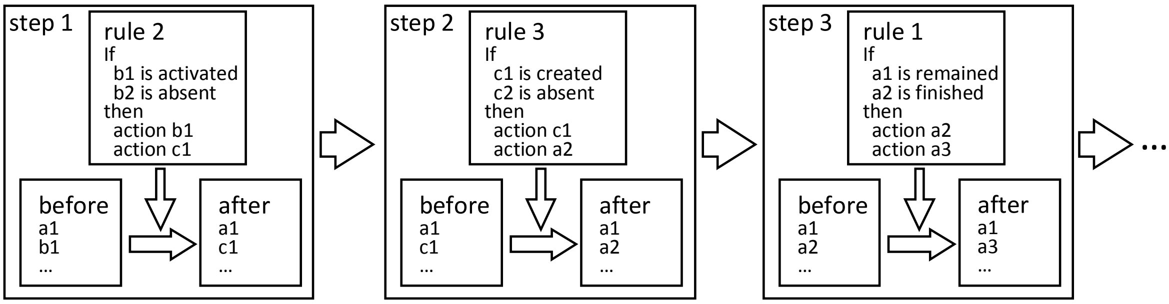

Figure 2. Structure of information of processes from model execution

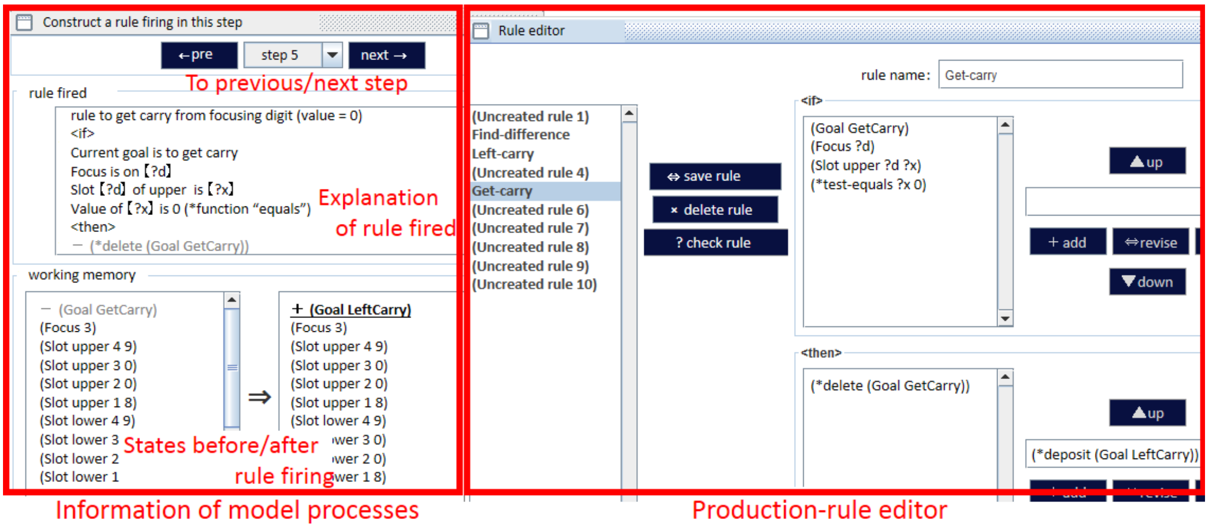

Figure 3. Screenshot of support system

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