Mohd Ayub A. F. et al. (Eds.) (2011). Workshop Proceedings of the 19th International Conference on Computers in Education. ChiangMai, Thailand: Asia-Pacific Society for Computers in Education.

Preliminary Evaluation of an Intelligent Authoring System for 'Graph of Microworlds'

Tomoya Horiguchi[a*] **& Tsukasa Hirashima**[b]
[a]*Graduate School of Maritime Sciences, Kobe University, Japan*
[b]*Department of Information Engineering, Hiroshima University, Japan*
* horiguti@maritime.kobe-u.ac.jp

Abstract: *Graph of Microworlds* (GMW) is a framework for indexing a set of microworlds for computer-supported adaptive and progressive learning with microworlds. It is difficult to describe a GMW because an author must make a set of microworlds and organize them with model-based indices. Therefore, we proposed a method for semi-automating the GMW-authoring and evaluated it by hand simulation. In elementary mechanics, a GMW of practical size could be described with the method and each microworld was judged to be effective as a learning material. Additionally, by 7 subjects, the explanations generated by the method were judged to be useful in describing a GMW.

Introduction

In physics education, it is important for a student to acquire the ability to make appropriate models of various phenomena in the domain. For this purpose, a set of problems are provided in which he/she must think about some physical systems and their behaviors. In each problem, the range of systems and their behaviors are usually limited from some educational viewpoint in order for him/her to be able to understand the laws/principles behind the phenomena. This is called a *microworld*. For the systematic understanding of the domain theory, therefore, it is necessary to sequence a set of microworlds of various complexity (from relatively simple systems/phenomena to more complicated ones) adaptively to the context of learning.

In designing ITSs (Intelligent Tutoring Systems) with such a function, it is essential to appropriately index a set of microworlds. Especially, it is important to explain why, in the situation given by a microworld, the laws/principles are applicable and why the model is valid. It is also important to explain why/how the model changes if the situation is changed. In order to make such explanations, it is necessary to index a set of microworlds based on their models and the process of modeling.

Therefore, we proposed the *Graph of Microworlds* (GMW), which is a framework for indexing the microworlds and the relations between them based on their models and the process of modeling [4]. We also showed, by using GMW, it becomes possible to design a function for adaptively selecting the microworld which a student should learn next, and a function for assisting a student in transferring between microworlds.

However, it isn't easy to describe a GMW because an author must make a lot of indices in a model-based way. He/she must have the expertise in the process of modeling. Therefore, we also proposed a method for semi-automating the description of GMW by introducing an automatic modeling mechanism [5] (i.e., compositional modeling [3, 6]). Though the authoring system which implements this method is currently under construction, we described the domain knowledge for it which covers elementary mechanics and successfully simulated its behavior by hand. In this paper, we report the result of a preliminary experiment which was conducted by hand-simulation and validated the usefulness of our method.

1. Graph of Microworlds and its Authoring

An example of GMW for elementary mechanics is shown in Fig. 1. Each microworld is indexed with the situation it deals with, the model of the situation and the process of modeling. A student can learn the physical law(s)/principle(s) necessary for the modeling and the skill(s) for the model-based problem solving in each microworld (they are called a learning item). Two microworlds which deal with similar situations but different models (i.e., different law(s)/principle(s) is(are) necessary) are linked to each other with an edge. Parameter-change rules [1] are attached to such an edge which relate the difference between the situations of two microworlds to the difference between the behaviors of their models. This means one model is the necessary evolution of the other (with the perturbation of situation). Such a relation between two microworlds is called an educationally meaningful relation. In order to make a student learn the domain theory progressively [2], a GMW should include as many such relations as possible.

Fig. 2 shows the framework for authoring GMW. An author describes a GMW as follows: Suppose a learning item network is given which consists of a set of concepts and their partial ordering to be learned. First, he/she finds a situation for learning an item. Then, he/she perturbs the situation to make a new situation for learning another item adjacent to the former. For each situation, the system generates its model and indexes it with its modeling assumptions automatically by *compositional modeling* [3, 6]. By repeating such perturbation, he/she finally gets a GMW which covers the learning item network. In this process, the system generates explanations about the differences between situations to help an author judge whether they have 'educationally meaningful' relation or not (the detail for generating explanations is described in [5]).

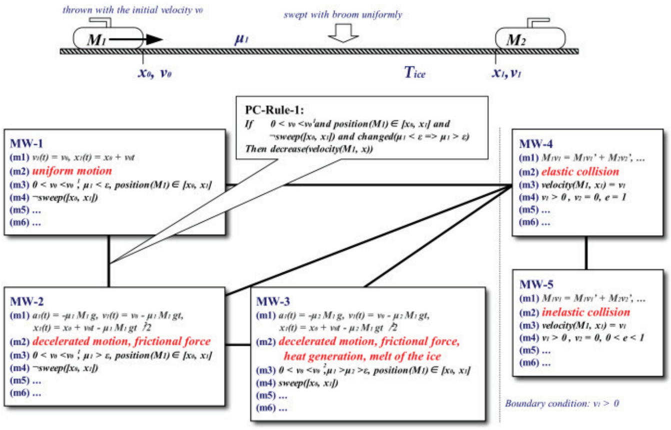

Fig. 1. An example of Graph of Microworlds.

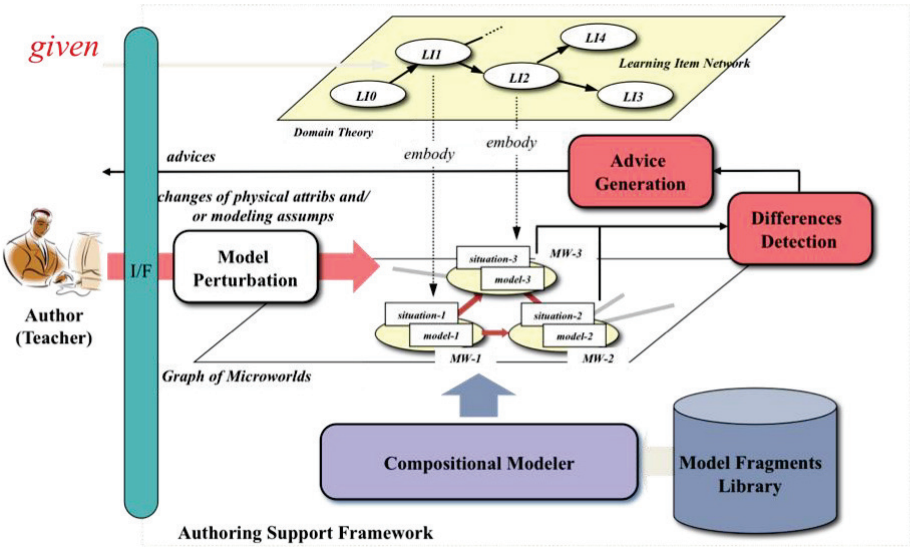

Fig. 2. Framework for authoring GMW

2. Preliminary Experiment

2.1 Design of the Experiment

First, we examined whether one can describe a GMW covering a given learning item network of practical size with our method. We made a learning item network of elementary mechanics (which includes 38 learning items and is partially shown in Fig. 3) by analyzing 2 textbooks in physics for senior high schools. We then tried to describe a GMW which covers it with the method.

Second, we examined whether each microworld made in the above process can be effective in learning the corresponding learning item. A microworld was judged to be effective if a problem which deals with the same item and the same situation as it was found in text/exercise books[1].

Third, we evaluated the ability of the method to generate explanations about the differences between microworlds. In text/exercise books, there aren't always 'educationally meaningful' relations between two situations of the problems which deal with adjacent learning items. Therefore, after selecting 6 such pairs of problems from text/exercise books, we made the 'bridging' microworlds with our method (a 'bridging' microworld has 'educationally meaningful' relations with both problems in a pair). We then asked 7 subjects (who were under/graduates majoring in engineering) to judge whether these microworlds were effective in facilitating progressive learning and whether the explanations generated with the method about their differences were useful.

2.2 Results

First, a GMW covering the learning item network shown in Fig. 3 could be described with the method. It, besides the microworlds corresponding to the given items, has 4 extra microworlds each of which was inserted to bridge the gap between two microworlds (where one couldn't make the adjacent microworlds corresponding to adjacent items by perturbing the situation). Though the GMW was described by the authors, we think it reasonable

[1] We assumed the situations of the problems in text/exercise books were guaranteed to be effective in dealing with the corresponding learning items, and tried to reproduce as many such situations as possible when describing the GMW.

because the purpose of this experiment is to evaluate the ability of the method to make models by perturbing situations (not the usability for end users).

Second, every microworld except one[2] in the GMW (partially shown in Fig. 3) could be made the same as the situation of the problem in text/exercise books (we referred 5 ones). Therefore, the microworlds made with the method can be effective in learning the corresponding learning items.

Third, the evaluation result by the subjects about the effectiveness of the 'bridging' microworlds is shown in table 1. It reveals that the inserted microworlds between those of too different situations were effective in complementing the gaps with 'educationally meaningful' relations, and that the explanations generated with the method were useful in understanding the differences between microworlds (in case-1 and 4). Even though the effectiveness of the microworlds was negatively evaluated since they were inserted between those which weren't judged to be too different, the usefulness of the explanations by the method were positively evaluated (in case-2, 5 and 6). That is, in all the cases, the method could generate useful explanations for understanding the differences between microworlds.

In this experiment, because we tried to reproduce as many situations of the problems in text/exercise books as possible when describing the GMW, some edges became ineffective in facilitating progressive learning (i.e., in case-2, 5 and 6). This matter, however, could be improved when such constraint is removed.

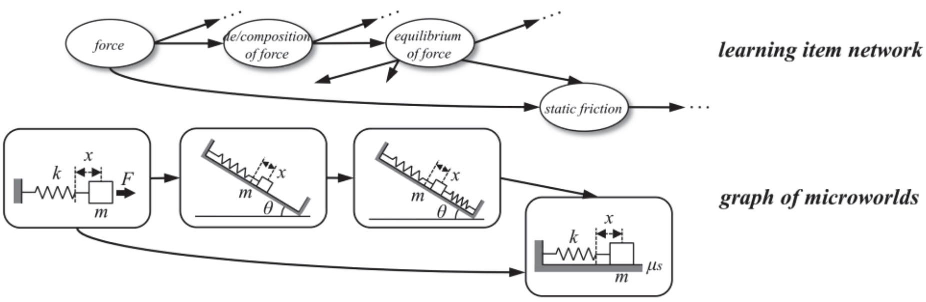

Fig. 3. Learning item network and a GMW covering it

Table 1. Evaluation result about bridging microworlds

	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6
Q1	0.86	2.43	2.00	1.43	3.29	3.57
Q2	3.57	1.43	2.14	3.29	2.43	1.29
Q3	3.43	2.86	3.00	3.71	3.00	2.57

Q1: Are the situations of two microworlds close enough to facilitate progressive learning?
Q2: Is the microworld inserted between two microworlds effective in facilitating progressive learning?
Q3: Is the explanation by the system useful to understand the difference between situations?
*Each score is the average of five degree ratings by 7 subjects (0: the most negative - 4: the most positive).

3. Conclusion and Future Work

These results suggest our method is useful in describing a GMW covering a learning item network of practical size which effectively facilitates progressive learning. One of our important future work is to complete the prototype by adding a GUI-based interface and examine what GMWs could be described by end-user authors.

[2] Thirty-one microworlds (out of thirty-eight learning items) were examined because seven microworlds dealing with 'work' and/or 'energy' became the same situation as the others. Though the only exception was a microworld dealing with 'de/composition of forces,' its situation wasn't ineffective because it was a part of the situation dealing with the following learning item 'angled projection.'

References

[1] Addanki, S., Cremonini, R. and Penberthy, J.S.: Graphs of models. *Artifi. Intelli.*, 51: 145-177 (1991)

[2] Burton, R.R., Brown, J.S. & Fischer, G.: Skiing as a model of instruction, In Rogoff, B. & Lave, J. (Eds.), *Everyday Cognition: its development in social context*, Harvard Univ. Press (1984)

[3] Falkenhainer, B. and Forbus, K.D.: Compositional Modeling: Finding the Right Model for the Job, *Artifi. Intelli.*, 51, pp.95-143 (1991)

[4] Horiguchi, T. & Hirashima, T.: Graph of Microworlds: A Framework for Assisting Progressive Knowledge Acquisition in Simulation-based Learning Environments, *Proc. of AIED2005*, pp.670-677 (2005)

[5] Horiguchi, T. & Hirashima, T.: Intelligent Authoring of 'Graph of Microworlds' for Adaptive Learning with Microworlds based on Compositional Modeling, *Proc. of AIED2009*, pp.207-214 (2009)

[6] Levy, A.Y., Iwasaki, Y. & Fikes, R.: Automated model selection for simulation based on relevance reasoning, *Artifi. Intelli.*, 96, pp.351-394 (1997)

[7] White, B. & Frederiksen, J.: ThinkerTools: Causal models, conceptual change, and science education, *Cognition and Instruction*, 10, pp.1-100 (1993)

[8] White, B. & Frederiksen, J.: Causal model progressions as a foundation for intelligent learning environments, *Artifi. Intelli.*, 42, pp.99-157 (1990)