

BRIDGING AUTOMATIC PROBLEM GENERATION SYSTEM AND LEARNING SUPPORT SYSTEM FOR HUMANS' PROBLEM GENERATION

Kazuaki Kojima and Kazuhisa Miwa

Graduate School of Information Science, Nagoya University, Japan

1. INTRODUCTION

In general mathematical learning, a teacher first presents a solution method with example problems to students, who then learn by solving problems as analogical instances. Since a number of problems is needed in such mathematical learning, teachers generally use multiple workbooks to provide students with a variety of problems.

Word problems, perhaps the most typical type of problem in mathematical learning, have two essential attributes for problem solving: surface problem situations denoting contextual settings expressed in texts such as "purchase of goods" and "transfer by vehicles," and the mathematical structures of solutions. In mathematics education, providing students with problems that have various features in both surface problem situations and deep mathematical structures is crucial [1]. Moreover, in problem-posing education, it has also been pointed out as important but difficult to generate a broader range of problems from formal symbolism and informal situations [2]. Therefore, it is beneficial to implement the automatic generation of various word problems controlled by both features in the problem situations and solutions. Furthermore, it is also beneficial for learning mathematics to support learners in generating word problems that have various features in problem situations and solutions.

Based on the background described above, we have developed an automatic generation system for word problems that provides problems for mathematical learning. The generation system can produce a problem database that contains various features of problem situations and solutions. We have also developed a support system for problem generation by learners as users to help them generate a broader range of problems. The support system incorporates and uses a problem database produced by the generation system. Figure 1 shows the relation between the generation and support systems.

2. AN AUTOMATIC GENERATION SYSTEM OF WORD PROBLEMS

We implemented a system that generates various mathematical word problems based on controlling problem situations and their solutions [3]. The generation system aims to expand the variety of problems by generating new ones from the initial problems stored in the system; but to generate word problems, such technical issues as commonsense reasoning must be overcome. To tackle these issues, we adopt the following two approaches: (1) the system forms and uses episodes of problem generation, and (2) it acquires common knowledge through interactions with a teacher as a user. Each episode is knowledge regarded as a case where a new problem is generated from an example one, and it contains these two problems and their relationships. Thus, an episode can be considered a meta case comprised of two problems as cases.

The generation system was evaluated in regard to the following viewpoints: (1) whether it can appropriately generate new problems and expand the variety of problems, and (2) whether it can acquire effective knowledge through interactions with a user. To verify the first viewpoint, we conducted performance tests to evaluate problems automatically generated by the system from initial problems, and to verify the second viewpoint, we conducted application tests to confirm the appropriateness of the system's interactions with general users.

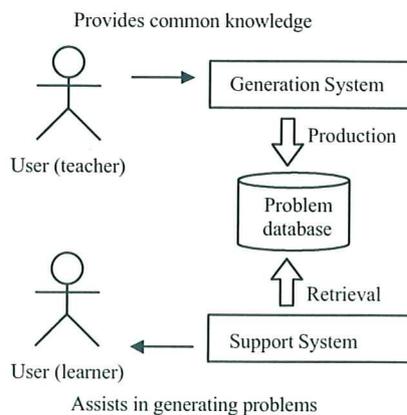


Figure 1. Relation between generation and support systems

The results of the performance tests confirmed that the system can appropriately generate new problems and expand the variety of problems from the initial problems.

In the application tests, we asked participants as users to interact with the system. The participants were undergraduates as novices in the domain of mathematics, and a mathematics teacher and graduates majoring in mathematics as experts. The participants were asked to evaluate and revise problems generated by the system. As the results, it was found that novice participants could not necessarily revise problems appropriately. In contrast, expert participants appropriately revise problems, indicating that the system needs interactions with knowledgeable users.

3. A SUPPORT SYSTEM FOR PROBLEM GENERATION BY A LEARNER

We implemented a system that supports learners as users in generating word problems by presenting problems as cases by controlling similarities in the two attributes of problem situations and solutions. Prior to the implementation of the support system, we experimentally confirmed that the presentation of cases by controlling the similarities provided constraining effects to human problem generation [4]. In the system implementation, our focus is on the aspect of problem generation as a creative generation task where the production of various and appropriate problems is critical. The support system gives users a task to generate new problems from an example problem and assists them to appropriately generate various problems. Our system supports users by evaluating their problems based on the similarities in the two attributes of the problem situations and solutions and by presenting problems as cases that have various features of these two attributes.

Since the support system requires a variety of problems to function properly, it is assumed that the support system stores many problems propagated in advance by the generation system.

In the support system, a user is first given an example problem and prompted to generate a new one from it. The user generates and inputs the problem into the system. In this phase, it in turn requires following: (1) objects to appear in the problem text (such as apples or pencils), (2) numeric values to be included in the text for solving the problem, (3) equations for solving the problem, and (4) the problem text itself. The system analyzes the numeric values and equations to verify whether the solution can be solved and rejects any problems that have inappropriate solutions. The user's problem is represented in the generation system's data format, where the solution is represented in operational procedures needed to evaluate the answer and the situation is represented by a label estimated from the words in the problem text, such as "*purchase of goods*." To

estimate labels denoting problem situations, the support system uses situation-estimating models, each of which is constructed from independent words in the texts of problems in the problem database that includes identical situations. The situation-estimating models can never, however, identify novel situations that are not included in problems in the problem database. Thus, the support system can basically only estimate situations seen as typical and well-known problems; it supposes that other situations are novel in some way.

The support system then evaluates the user's problem by showing the similarities between the example problem and his/her problem. Simultaneously, the system retrieves and presents problems as cases. As described above, since the support system incorporates a problem database of the generation system, it can present various cases by controlling the similarities in the problem situations and solutions, such as presenting problems whose solutions are identical to and whose situations are different from the user's problem.

4. CONCLUSION

In this paper, we introduced an automatic generation system for word problems to provide problems in mathematical learning and a support system for problem generation by learners as users to assist them in generating a broader range of problems. Based on a cognitive psychological background, we believe it is important to generate word problems that have various features in problem situations and solutions both by computer systems and by humans. Thus, we implemented functions to generate various word problems and to present the problems to learners while controlling the similarities in the problem situations and their solutions.

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