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An Analysis and Detection of the Opportunities for Learning Activities within Automatically Generated Educational Games

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Abstract: We proposed a design method to automatically generate an educational game by substituting the cards of an existing card game for new cards that have practice problems written on them. However, several games in which most players rarely solved problems were created by the method. Therefore, this study examines the reasons why they rarely solved problems. We conducted an experiment that asked test subjects to play useful and useless educational games and their reactions were videotaped. The video recordings and interviews suggest that few subjects solved problem in playing the educational games had no opportunities for solving problems to predict the future game state that would result from each choice to make a favorable choice. On the other hand, all subjects solved problems in playing the educational game had opportunities for the prediction. On the basis of the results, this study also organizes the rules that provides the prediction, and develops a system that detects useless educational games. The results of experimental evaluations of the system suggest that the detection system can detect useless educational game by the detection of the rules for the prediction.

Keywords: Educational game, authoring, analysis of learning activity, automatic generation

1. Introduction

We have been studying how to create educational game that enables formal learning activities in the form of a game. As a product of this study, they have organized and analyzed the rules of card games, and have proposed an EPIC (Embedding Problem-exercises Into a Card game) method to create an educational game that incorporates cards that have educational practice problems written on them into the rules (Umetsu, Hirashima, and Takeuchi, 2006). Using this method, an automatic generator for educational game applications has been developed (Umetsu, Azuma, Hirashima, and Takeuchi, 2011).

The EPIC method transforms an existing card game into an educational one by substituting the cards of the existing card game for new cards that practice problems are written on them. Thus, according to the game created by this substitution, a player has to derive answers form the problems, instead of using the properties of the original cards. Therefore, we expect that the game may be understood as an educational game for problem-solving exercise.

However, several games were created with the EPIC method in which most players rarely solved problems (Umetsu, Baba, Hirashima, and Takeuchi, 2012). The circumstances suggest that it is unclear as to why players solve problems, and what game rules make the players solve problems. Therefore, this study examines the reasons why players solve problems in educational games created with the EPIC method. As the result of the experiment, we found that few subjects solved problem in playing the educational games that had no opportunities for solving problems to predict the future game state that would result from each choice to make a favorable choice. On the other hand, all subjects solved problems in playing the educational game had opportunities for the prediction.

To detect useless educational game or to design useful educational game, it is necessary to clarify which rules of an educational game provide opportunities for the prediction in playing the educational game. Therefore, this study also organizes the rules for the prediction, and develops a system that detects these rules from educational games generated by the automatic generator on the basis of the EPIC method.

2. Method to Design Educational Games

There have been several investigations into the design methods for educational games; however, most of these studies have dealt only with a limited part of the design process. On the other hand, this study analyzes concrete methods to embed problem-solving exercises into existing card games as well as examination of the reasons why players carry out the learning activities.

We have proposed a concrete method to design educational games automatically. We call the method “EPIC method”. In EPIC method, an existing card game is transformed into an educational one by substituting the cards of the game for cards with problem statements. To play in accordance with the rules of the game, players have to solve the problems provided on the substituted cards, instead of using the property of the original cards. Figure 1 shows the framework for the EPIC method.

A card game is any game using cards as the primary device with which the game is played. The activity of playing the card game involves moving the cards following a given set of rules. Certain rules, determine how a player should move the cards, depending on values of cards’ properties. In playing the game, the operations of the cards are decided on the basis of three evaluations of the card’s value: assignment, comparison, and calculation. Therefore, we transformed an existing card game into a playable new game by substituting cards in the game for those having properties that are based on the three evaluations can be performed.

In other words, a new game can be developed by substituting cards from an existing card game for cards with problem statements, which consists of given information and questions. The question and corresponding answer are used instead of the property of the original card and the value of the property, respectively. Thus, according to the game created by this substitution, a player must derive answers from the given information because the movement of the cards by a player depends on the properties of the cards.

We have developed an authoring system on the basis of the EPIC method. The authoring system can generate a computer-based educational game from text of rules that consists of words or sentences that are used to describe rules of a card game.

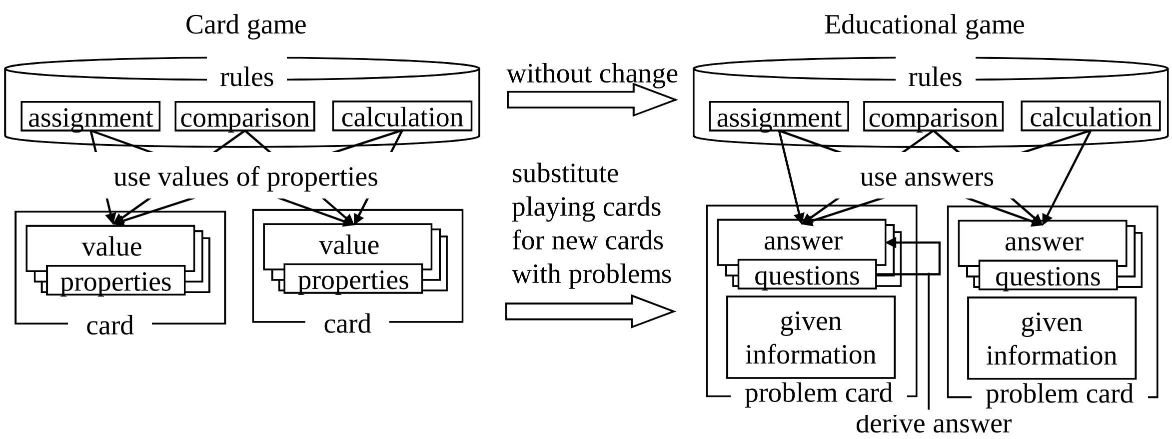

Figure 1. Framework of EPIC method.

3. Analysis of Reasons for Carrying out Learning Activities

In playing the game created by EPIC method, answers of problems are required. Nevertheless, several games were created with the EPIC method in which most players rarely solve problems (Umetsu et al., 2012). This suggests that it is unclear as to why players solve problems, and what game rules make the players solve problems. Therefore, this chapter examines the reasons why players solve problems in useful and useless educational games created with the EPIC method.

3.1 Reasons for solving problems

On the basis of EPIC method, we speculate on the reason why players solve problems. We expect that there are three reasons for solving problems. In playing a card game, there are three evaluations of the card's value: assignment, comparison, and calculation. Generally in a game application, the evaluations are automatically performed by the game application to relieve players of the tasks. The game state is changed automatically on the basis of the results derived by the application. An educational game created with the EPIC method substitutes the card's value for answer of problem. Therefore, generally in the educational game application, the evaluations are automatically performed by the educational game application.

In such case, (1) to find out the details of this automatically processed state transition, the player has to solve the problem to obtain the answer that is necessary for analyzing the automatically processed transition procedure. A player occasionally wants to check the automatic operations. Because the answers of the chosen cards are required for finding out the state transition, the player solves the problems written on the cards.

However, it is unlikely that there are many players who solve problems to find out the details of the automatically processed state transition. Therefore, the educational game in which a player has to change the game state manually is created to force the players solve problems. In such educational game, (2) the player has to solve the problem since obtaining the answer to the problem is necessary for carrying out the correct transition in accordance to the rules, because the transitions are correct or not depending on the answer.

The manual transitions make players solve problems. However, it may be cumbersome to play the manual game. Therefore, we have placed emphasis on the following reason for solving problems. (3) A player is usually required to make a choice in playing game. The player solves the problem since obtaining the answer to the problem is necessary in order for the player to make a favorable choice. To make favorable choice, the player has to predict and evaluate the future game states that are results of each choice. The answer is necessary for predicting the future states, because the future states depending on the answer.

As an exception, we think that (4) a player might solve the problem for no particular reason, such as the problem written on the card entered the field of vision.

3.2 Examination of the reasons

We conducted an experiment to clarify the reasons why players solve the problems and examine the reasons. Test subjects were asked to play games created with the EPIC method, and their reactions were videotaped. In addition, the subjects were told to press a button when they had solved each problem, and the timings of problem solving were recorded. Later, whilst showing the test subjects these video recordings, an interview survey was conducted on the subjects to investigate "when" they solved the problems and "how" they came to solve the problems.

In this experiment, 20 test subjects played each of the four educational game applications created by the automatic generator for ten minutes. All four educational games incorporated problem-solving exercises that were based on arithmetic formulas using three-figure numbers. The 20 test subjects could solve the problems easily because they were of the university level.

Two of the four educational games had no opportunity for solving problems to predict the future state that would result from each choice to make a favorable choice (Reason (3)). They were created from Old Maid game. One of the two educational games was general game which state was changed automatically. Therefore, the game had opportunities for solving problems to find out the details of this automatically processed state transition (Reason (1)). The other one of two was specially-designed game in which a player had to change the game state manually. The other two of four educational games had opportunities for the prediction. One of the two was created from Sevens game. The other was created from Daifugo game. We confirmed that players solved the problems for these reasons by playing the games many times.

Table 1 shows the number of players who solved problems with each reason. The diagonal line area in Table 1 meant there was no subject who solved problems with the reason. (4) meant the number of players who solved problems for no particular reason (Reason (4)). Table 2 shows average number of problems one player solved (rounding to one decimal place). The 20 subjects fell into four groups. Group A consisted of two subjects who solved problems with Reason (1), (2), (3), and (4). Group B consisted of three subjects who solved problems with Reason (1), (2), and (3). Group C consisted of 15 subjects who solved problems with Reason (2) and (3). The number in Table 2 shows average number of solved problems in these groups. The table suggested that although there were multiple opportunities for solving problems with Reason (1), or (4), the Group B didn't solve problems with Reason (4) and the Group C didn't solve problems with Reason (1) and (4).

The results suggest that Reason (1) and (4) make few players solve problems. In addition, even though there were multiple opportunities to solve the problems with (1) and (4) as their reasons, the subjects only solved a small fraction of the problems available in the manner. Although the all 20 subjects solved problems with Reason (2), educational game that requires the player to change the game state manually was useless. This is because the changing states manually are cumbersome. We asked the 20 subjects to answer the question about the Old Maid (manual), as follows:

- Was the manual game enjoyable than the automatic one?
  never want to play the manual game, disagree, as same as, agree, never want to play the automatic game

The result of the question was that 6 subjects chose "never want to play the manual game," and the other 14 subjects chose "disagree". The result suggests that the manual game was unappreciated in terms of motivating the 20 test subjects.

On the basis of the results of the experiment, we have placed emphasis on Reason (3). Therefore, to detect whether or not an educational game has opportunities for solving problems for the prediction or to design useful educational game, it is necessary to clarify how provide the opportunities for solving problems for the prediction. Under the circumstance, this study clarify what kind of game rules provides the prediction, and develop a system that detects these rules from educational games generated by the automatic generator on the basis of the EPIC method.

Table 1: Number of payers who solved problems with each reason.

	Old Maid (automatic)				Old Maid (manual)				Sevens (automatic)				Daifugo (automatic)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Number of players	5			2		20		2	5		20	2	5		20	2

Table 2: Average number of problems one player solved with each reason.

	Old Maid (automatic)		Old Maid (manual)		Sevens			Daifugo		
	(1)	(4)	(2)	(4)	(1)	(3)	(4)	(1)	(3)	(4)
Group A	12.0	8.0	13.0	5.5	8.0	18.0	4.0	18.5	26.0	8.0
Group B	15.3	0.0	23.0	0.0	11.7	20.7	0.0	11.3	26.3	0.0
Group C	0.0	0.0	24.5	0.0	0.0	33.7	0.0	0.0	36.3	0.0

4. Solving Problems to Predict the Future State to make a favorable choice

On the basis of the experiment in previous chapter and an examination of 184 card games, we organized the game rules that provide opportunities for solving problems to predict the future game state that will result from each choice to make a favorable choice.

These rules basically provide opportunities, and it depends on the learners themselves as to whether the learning activity actually takes place. Moreover, this study cannot currently deal with frequency of opportunities in playing a game. The calculation of the frequency remains to be solved. It is to be noted that there are predictions that confirm the definite transition to the next state, and there are uncertain predictions in which there are high probabilities of transitioning to a new state. This study is only concerned with the determinable predictions.

To provide the prediction, the state of an educational game must satisfy five requirements. If (i) a player make a choice, (ii) the choice alters the future state of a game, and besides that, if (iii) the answer alters the future state of playing game, the answer becomes necessary in predicting the future state of playing game. Also, to make prediction, (iv) it is necessary that the information related to the ruling of the state transition is available to the player. In addition, once the information is available, the operation that conceals the information doesn't make the information unavailable as long as the information remains unchanged because a player can memorize the information. (v) Since other operations may change the information related to the ruling of the state transition between the choice making and executing the state transition caused by the choice, it is a necessary that the information related to determining the state transition remains unchanged by such other operations.

To provide the situation for the prediction, it is essential for an educational game to have the rules that result in the five requirements. We describe the rules in terms that are within the card game model (Umetsu et al, 2011). The card game model is a structured representation of the nouns, verbs, sentences from the rules of card games.

For the requirement (i) a player make a choice, the game has to have one of four rules: "<player> choose <any>," "<player> assign <value> to <parameter>," "<player> move <card> from <field A> to <field B>," or "<player> flip <card> in <field>." For the requirement (ii) the choice alters the future state of a game, a conditional statement of any "if-then rules" has to include the chosen one by the player in those four rules (<any>, <value>, <parameter>, <card>, or <field>)." For the requirement (iii) the answer alters the future state of playing game, the conditional statement of the "if-then rule" has to include the answer of any cards.

For the requirement (iv) the information related to the ruling of the state transition is available to the player, all parameters in the conditional statement have to be available. The parameters are variables, constants, properties of cards, and number of cards. Variables and constants are always available. Properties and number of cards are described in "card field" rule in which there are the cards.

For the requirement (v) the information related to determining the state transition remains unchanged by other operations, it is necessary that there is no rule that change the parameters of the conditional statement of the if-then rule between the choice making rule and the if-then rule. There are five kinds of rules that change the parameter: "choose <card>," "move <card>," "shuffle <card field>," "assign <value> to <parameter>," "change order of <parameter>." If the <card>, <card field>, <value>, or <parameter> is the parameter of the conditional statement, the information related to determining the state transition is changed by the rules. If the rules couldn't find by running a full search on sequence of operations between the choice making and the if-then rule, the requirement (v) is satisfied. Since the same parameter is sometimes described in different words, it is necessary to determine whether or not they are identical. Because of page limitation, the explanation of the determination is leaved out.

5. Detection System and Evaluations

We develop a system that detects the rules for the prediction from an educational game generated by the automatic generator. The generator can generate an educational game application from text of rules that consists of words or sentences that are within the card game model. The detection system searches the text for the rules for learning activities, and shows the rules to users. To evaluate the detection system, we conducted two experimental evaluations.

For the first evaluation, the detection system detected the rules for the prediction from the four educational games as mentioned in chapter 3. On the basis of the detection, we derived opportunities for solving problems for the prediction. Then, we examined the relationship between the opportunities and the time when the subjects solved a problem.

Table 3 shows the results. The opportunities included all the times when they solved the problem for the prediction (precision 100%). Although the subjects didn't always solve problems at every opportunity, the results didn't suggest that the accuracy of the detection system was low. These were basically opportunities, and it depends on the subjects themselves as to whether the subjects actually solved problems. We ask the subjects the reasons of the problems unsolved.

They answered “It was not necessary to solve problems, because I had solved the problem before and remembered the answer.” and “It was not necessary to solve all problems, because could find a favorable choice by solving some of the problems.”

For the second evaluation, we created 56 educational games with the generator (the four educational games in the first evaluation were not included), and the detection system detected the rules for the prediction from the 56 games. We played the 56 games for 10 minutes and found opportunities for the prediction.

As the result, the opportunities we found in 54 of the56 games were provided the detected rules (precision 96.4%). In the other two games, there were the rules that flipped the card and replaced the card after the flip operation. It is difficult to evaluate the combination of the two rules provide the prediction or not. The detecting system was defective in the ability to evaluate the combination.

On the other hand, we found opportunities for the prediction in four of 56 games but the detection system detected no rule from the four games (recall 92.9%). The reason of this was that the detection system detected wrong rules. The rules were trouble-free operations that changed no information related to the ruling of the state transition. However, the detection system mistook the trouble-free rules for the rules that changed the information.

In addition, the result of the second evaluation suggests that the detection system could detect useless educational games. The detection system found eight of the 56 games have no rule for the prediction. The eight games were the games judged to be useless games because most players rarely solved problems in previous research (Umetsu et al, 2012).This study can explain why few players solved problem in the eight games. Because there was no opportunity for the prediction, the eight games were useless for most players.

These results suggest that the detection system can detect the rules for the prediction and useless educational game.

Table 3: Number of solving problems and number of detected opportunities for solving problems.

	Sevens	Daifugo
Precision	100.0% (505/505)	100.0% (603/603)
Solving / Opportunities	63.8% (505/792)	78.4% (603/769)

6. Conclusions

This study examined the reason why several educational games in which most players rarely solved problems were created with EPIC method. We conducted an experiment that asked test subjects to play useful and useless educational games and their reactions were videotaped. The video recordings and interviews suggest that few subjects solved problem in playing the educational games had no opportunities for solving problems to predict the future game state that would result from each choice to make a favorable choice. On the other hand, all subjects solved problems in playing the educational game had opportunities for the prediction.

On the basis of the results, this study also organized the rules that provide the prediction, and developed a system that detected useless educational games generated by the automatic generator. We conducted experimental evaluations of the detecting system. The results suggested that the detection system could detect the rules for the prediction. The detection system could also detect useless educational game by the detection of the rules for the prediction.

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