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Collaborative Process Among Learning Support Agents in Game-based Learning Environment

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Abstract: Many studies and systems that use "pleasure" and "fun" as inherent elements in games to improve a learner's motivation have been developed in the field of learning environments. However, there are still few studies of situations where many learners gather at a single computer and participate in a game-based learning environment and where a computer designs the learning process by controlling the interactions (such as competition, collaboration, and learning by teaching) between learners and others who are learning by observation alone. Therefore, in this study, we propose a method (involving interaction control between learners) that generates interaction between learners intentionally to create a learning opportunity that is based on the knowledge understanding model of an individual learner. In this paper, we explain a game-based learning environment called "Who becomes the king in the country of mathematics?", in which we have incorporated a "learner support agent" to support each learner and a "game control agent" to control the game. Furthermore, we explain an example of collaborative process among learning support agents.

Keywords: game-based learning environment, interaction among students, motivation, pedagogical agents, junior high school

Introduction

In recent year, the popularity of computer games have grown enormously. The population using such games has increased by not only by the development of portable games, which users can play anywhere and anytime, but also by new types of game software which involve various new techniques such as the functions of comfortable manipulation, touch screens and speech recognition.

As a result, many studies and systems that use "pleasure" and "fun" as inherent aspects of games to improve a learner's motivation have been developed in the field of the learning environment [2, 4, 12, 13, 14, 15]. WEST is a game-based system that lets students learn elementary arithmetic skills [3]. In this system, the player tries to go to his hometown by making operational expressions that include different operations with three numbers given by roulette and by deciding on an advanced number. JULASSIC is a game-based education system that helps foreigners learning Chinese character idioms [8]. In this system, a fighting type game is introduced, and the player is enabled in the play with a computer-created player, too. Competing elements, puzzle elements and clever rules are planned for these learning environments. In them a computer designs a situation where a learner must come up with the most suitable method in each scene. The controls in these systems help the learner to concentrate on the game environment, and as a result, they improve his motivation.

It is believed that an action is not recognized for its learning activity when the action itself becomes the purpose of the learner in a game. Therefore, research is being carried out on

games that develop a real world “edutainment” in which learning is advanced in a real world which has become in the game a ubiquitous learning environment. Furthermore, workshops and special sessions about “edutainment” have been held recently in international conferences, and various arguments have been presented for these games, not only from technical points of view, but also from pedagogical, social and ethical points of view [5].

If we think about these games from the viewpoint of learning, there are the following implications for effects which they have. The first is that there is a need to improve motivation based on the pleasure and the fun that the games provide. The second is that the players acquire skills and knowledge by achieving the purpose of the game. Therefore, in this study, we try to design and develop a game-based learning environment that connects the effect of the game with learning. In other words, we build a learning environment in which the learner regards the game as having a "purpose" and the learning as being a "means” to that purpose.

There are many studies and practice lessons about games that use "pleasure" and "fun" as inherent elements. However, there are still few studies of situations where many learners gather at a single computer and participate in a game-based learning environment and where a computer designs the learning process by controlling the interactions (such as competition, collaboration, and learning by teaching) between learners and others who are learning by observation alone. Therefore, in this study, we propose a method (involving interaction control between learners) that generates interaction between learners intentionally to create a learning opportunity that is based on the knowledge understanding model of an individual learner. Furthermore, we implement this method with an agent system that incorporates a "learner support agent" to support each learner and a "game control agent" to control the game.

In this paper, we first consider the relation between pedagogical agent (PA) and game based learning environment. Secondly, we explain fun and learning volition in a game. Moreover, we describe the concept of a game-based learning environment that incorporates four viewpoints for the fun of the game, the rules and flow of the game, and an educational control method. At last, we illustrate the example of a collaboration process between the learning support agents and the game control agents.

1. Pedagogical agent and game based learning environment

Pedagogical Agent (PA) is defined as a agent that has some function about learning, education and training support. Therefore, the kinds of PA are various. For example, the PA was classified as follows by Dellenbourg from the viewpoint of the purpose to use it [6].

+ Sub-agent … the agent that carries out some kind of tasks for learner or group.
+ Co-agent … the agent that performs some learning activity with learner or group.
+ Super-agent … the agent that monitors the learning activity of learner or group and support her/him or group.

Moreover, Baylor arranges the characteristic of PA as follows from a point of view designing the effective PA; educational role, characteristic of media, human characteristic, type and quantity of educational feedback, and necessity of multiple Pas [1].

We can arrange the advantage for incorporating PA into learning support system as follows. At first, we can expect the re-use of each component from a developmental point of view. Secondly, we can expect adaptive support for learner or group by improving the power of collaboration among agents. Furthermore, we can expect the deepening of the understanding and the improvement of the learning volition for learning object by the development of interface technology. Based on the characteristic of this PA, we think the

game based learning environment is better to use as a field of studying PA. So, we'd like to study the research task such as the agent function and learning effect, and collaborative protocol among PAs as a domain of game based learning environment.

2. Fun and learning volition in games

It is said that the "fun" of a game depends on the situations in it. Users of games have classified this fun differently [9, 10]. Koster has stated the following four propositions with regard to the fun of games [9].

- Fun is the act of mastering a problem mentally.
- Aesthetic appreciation isn't always fun, but it's certainly enjoyable.
- Visceral reactions are generally physical in nature and relate to the physical mastery of a problem.
- Social status maneuvers of various sorts are intrinsic to our self-image and our standing in a community.

Based on these propositions, we classified fun in an education game into the following four types.

- **Fun when a player achieves a goal**
  In other words it is the good feeling a player has when he has achieved a goal. For example, "a player solves a certain problem," or "a player wants to beat competing other player, and he wins." We believe that the basic fun in a game comes from the good feeling of achievement.
- **Fun from what a player was unable to predict**
  In other words, fun is the intellectual or aesthetic feeling which occurs at the time of an unpredictable happening. For example, in the context of a story, it is a situation in a scene that the reader was unable to predict.
- **Elation when a player faces a challenging problem**
  In other words it is the surging feeling when a player faces a challenging problem or goal--for example, before a player steps on a roller coaster, or when a player considers whether he can solve a difficult problem or achieve a difficult goal.

- **Honor for the player**
- It is the feeling of satisfaction when a player receives social praise or honor, such as "the player is praised" or "the player achieves first place." However, the player does not always feel fun at the time of receiving the honor.

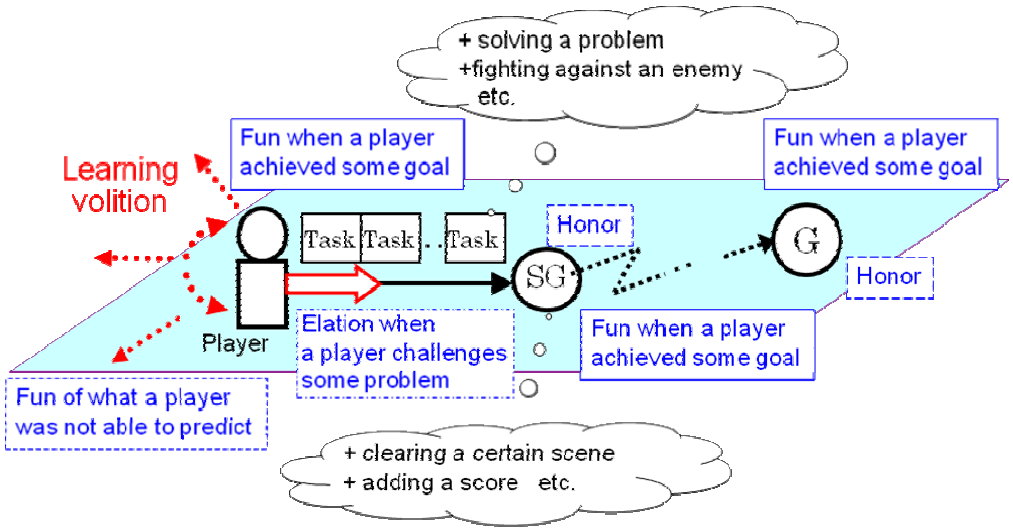

Figure 1. Fun and learning volition in an educational game

These four “funs” in an educational game lead to the maintenance and improvement of a learner’s motivation, and we believe that they give a game and the learning from it advanced power (see Figure 1). Therefore, in the design of a game-based learning environment, it is important that we incorporate these four viewpoints of fun into the scenes or phases of the game and learning that comes from it.

3. Fun and learning volition in games

In a game-based learning environment, it is effective for the maintenance and the improvement of a learner's motivation to develop the support that fun brings to the game. Therefore, we set three design indicators in consideration of the four types (fun when a player achieves a goal, fun when a player has an unpredictable experience, elation when a player faces a challenging problem, satisfaction when a player receives an honor) in the development of the learning design in the game-based learning environment. These are the following.

I. Setting a time limit and the number of problems (acquisition of a good feeling by a player when he achieves a goal).
II. Preventing a player from getting tired by having to prepare too much for a questions form for a problem (such as by a time trial, or having to check answers for other players) (acquisition of fun by being unable to predict something).
III. Setting a bonus point and various posts according to order (acquisition of honor for a player).

We made a learning design in the game-based learning environment based on the three indicators explained above.

a. The outline and rule of "Who becomes the king in the country of mathematics?” game

This game is a board game with roulette in which there are four players. The winner can become the next king of the mathematics kingdom.

From the roulette, the player receives a number to determine his forward movement. He then replies with an unknown value in solving a calculating formula in the roulette.

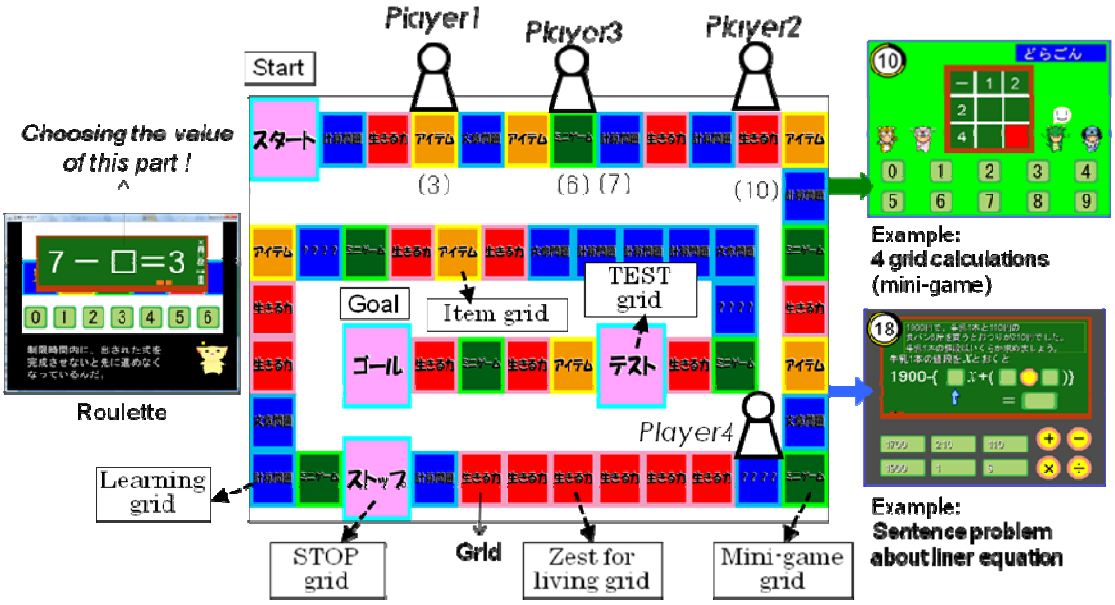

Figure 2. Image of game-based learning environment for linear equation

If the player solves the problem correctly, he can advance only the number of the answer. Next, the player carries out an event, such as the game or learning, on the grid on which he stopped. The player can increase the mark of a parameter (the learning power and the power of zest for living) of the organism which the player operates by clearing the event.

The player who has the highest general marks ([learning power] x [power of zest for living] + [bonus point]) becomes the winner when all players have reached the goal grid. At the end of the game, the first place player becomes the king of the mathematics kingdom. The second, third, and fourth place players are given a post depending on their general marks and the marks of two parameters for each player.

As different kinds of grids in this game-based learning environment, there are a "Learning grid," a "Zest for living grid," an "Item grid," a "Mini-game grid," and a "Special gird" (see Figure 2). The "Learning grid" has to do with solving a problem about the linear equation for the subject domain. We prepared five learning items about the linear equation in this environment. A calculation problem or sentence problem is set to each grid. When a player stops on a learning grid, a learning form depending on his learning situation is set to the grid. The "Zest for living grid" concerns solving a problem about intellectual, physical and moral competency. When a player stops on a "Zest for living grid," a story about a problem that is chosen depending on the experience situation of the player's learning forms occurs, and the problem is shown (for example, a problem about a moral or dietary education). The player must solve the problem by a method which computer points out. The "Item grid" is given by an item card which allows the player to advance only according to a number written on the card. The player can use the item card after his next turn. The "Mini-game grid" is about learning ability or the zest competency for living. The player carries the game such as "4 grid calculations" or "let's go out with me" either alone or while he competes or collaborates with other players.

On the "Special grid" the player must stop forcibly. There are a "STOP grid" and a "TEST grid" as special grids in the developed game environment. On the STOP grid, the player plays rock-paper-scissors with the computer. If he loses, then he must play rock-paper-scissors again on his next turn. In addition, when the player wins, a bonus point is given at random. On the TEST grid, the player must answer all the questions for each learning item correctly. If he makes a mistake, then he must return to a certain grid.

b. The method for educational control in the learning environment

The learning control in this game-based learning environment is performed by two kinds of agents (a "learner support agent" and a "game control agent") (see Figure 3). The learning support agent diagnoses the state of understanding of the learner for which the agent takes care and has the role of determining an effective learning task based on his diagnosis. This agent recognizes the state of understanding of the learner for each learning item in terms of the following five states.

Understanding state 0:

Because all learners do not carry out a problem of a learning item, the agent cannot recognize the state of the learner.

Understanding state 1:

Because other learners carry out a problem of a learning item, the agent recognizes that the learner may understand it by observing the situation.

Understanding state 2:

Because the learner makes one more mistake, although he carries out a problem of a learning item, the agent recognizes that the learner does not understand this learning item

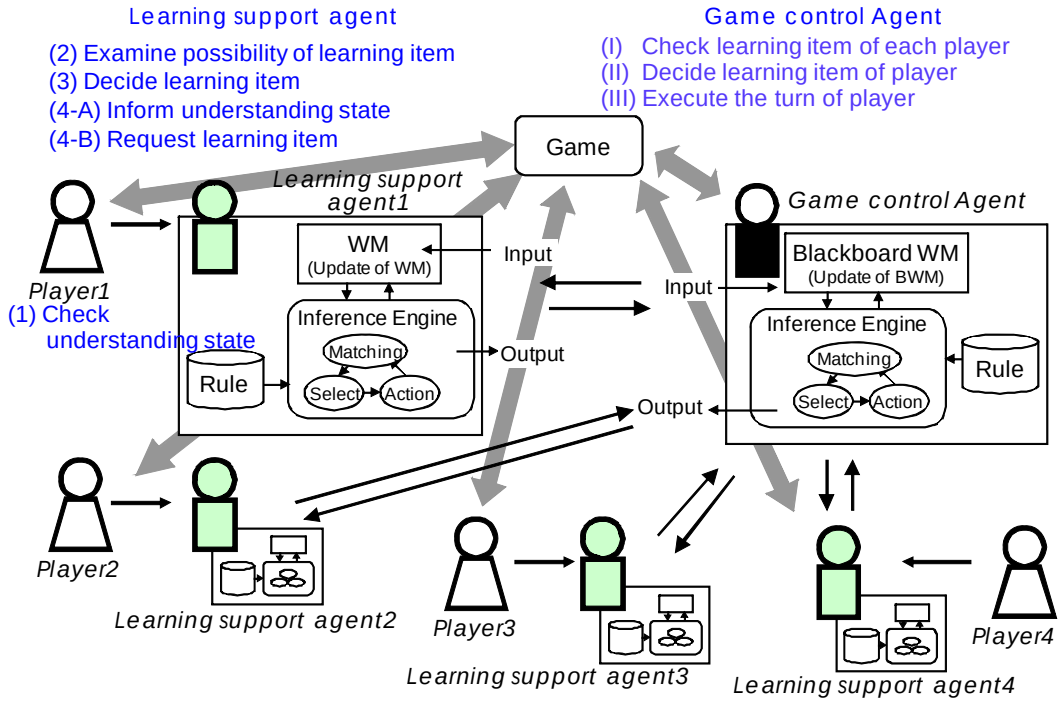

Figure 3. Framework of educational control in this environment

Understanding state 3:

Because the learner solves all problems of a learning item correctly, the agent recognizes he understands the learning item.

Understanding state 4:

When the learner succeeds in a challenge such as a "time trial" or "check answers with each other,"the agent recognizes that the learner understands the learning item deeply.

The learner support agent demands the learning item from the game control agent after determining the learning item of the learner. The game control agent receives information about the player's state of understanding and requests the next learning item from each learning support agent; he determines the learning item for the learner for his next turn and carries out the turn. When the learner needs learning control, the agent decides on a calculating formula and the answer by controlling the roulette. The agent has three learning forms; personal learning in which the learner himself solves a learning problem, collaborative learning in which the learner competes or collaborates with other learners, and observation learning in which the learner learns from other learners' problem solutions. The agent chooses a learning form based on the state of the learner's understanding for his next turn and for other learners.

4. Collaborative process among learning support agents

In recent year, various kinds of agent-based learning systems have been developed in the field of the learning environment [1, 7, 11]. In this chapter, we describe the example of the collaboration process between the "game control agent," who sets the problem of the learner, and the "learner support agent," who supports each learner. We consider the situation in Figure 2 where "Learner 1" stops at (3), "Learner 3" stops at (6), and "Learner 2" stops at

(10). The turn is that of "Learner 1." The state of understanding of the learning items for each learner is as follows.

Learner 1: (Learning item 1 = understanding_state 1)
(Learning item 2 = understanding_state 1)
(Learning item 3 = understanding_state 3)
(Learning Control Type = First_half)
Learner 2: (Learning item 1 = understanding_state 1)
(Learning item 2 = understanding_state 2)
(Learning item 3 = understanding_state 1)
(Learning Control Type = Latter_half)
Learner 3: (Learning item 1 = understanding_state 2)
(Learning item 2 = understanding_state 1)
(Learning item 3 = understanding_state 1)
(Learning Control Type = No_control)

Moreover, each "learning support agent" maintains the values of this situation (Figure 4). Before the turn of learner 2, "learning support agent 2" has already demanded the "trial of learning item 3" from the "game control agent." Furthermore, "learning support agent 3" demands the "trial of learning item 2" from the "game control agent" before the turn of learner 3. At this point in time, "learning support agent 1" estimates that the state of understanding of learning item 3 for learner 1 is "3," and learner 1 observes the solution process of learner 3 for learning item 1. Therefore, "learner support agent 1" demands the "trial of learning item 2" from the "game control agent". The "game control agent" recognizes that the learning control of learner 1 is the "First_half" type and decides to intervene in the scene of the game. Learner 2 is at the top of the game at this time, and the learning control is the "Latter_half" type. In addition, the learning control of learner 3 is "No_control." For these reasons, the "game control agent" decides on "learning item 2" as a learning item of learner 1 by considering a request from the "learning support agent" of learner 3. The "game control agent" notifies "learning support agent 1" and "learning support agent 3" of his choice. After having made these preparations, the "game control agent" expresses that the answer of the

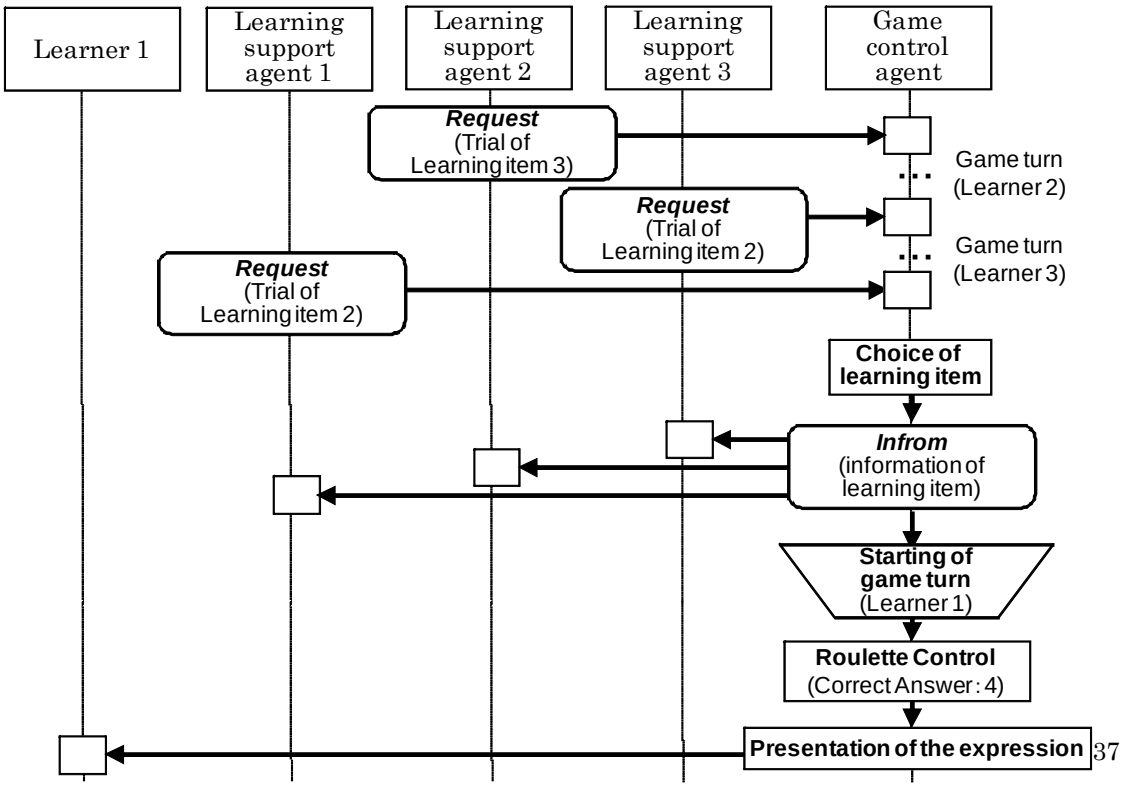

Figure 4. An example of collaboration process among agents

roulette will become "4" in learner 1's next turn and waits for an answer input from learner 1.

5. Conclusion

In this paper, we illustrated the design ideas of a game-based learning environment that incorporated four viewpoints for fun in the game, and we showed an outline of our game. Furthermore, we explain an example of collaborative process among learning support agents. The results from the development and practice show that it will be a problem in the future to provide a learning form and an expression method for learning contents because the tendency of learners is to not learn content that they cannot understand. In addition, it is necessary to consider a method for creating collaboration between agents through blackboard memory. Furthermore, we tried to analyze the content of interaction between learners during game enforcement and to examine the timing of the interaction and the support it provided.

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