A Personalized Game-based Learning System with Evenly Matched Competition Strategies

Chih-Yueh Chou[a], Shao-Pin Lu[a], Zhi-Hong Chen[b]
[a]*Department of Computer Engineering and Science, Yuan Ze University, Taiwan*
[b]*Department of Information Communication, Yuan Ze University, Taiwan*
cychou@saturn.yzu.edu.tw

Abstract: Appropriate challenge and uncertain outcome are key factors of motivating game based learning systems; that is, these systems attempt to keep students uncertain to win or lose until the end of the game. In this paper, we present a personalized game-based learning system, which is adaptive to different student game status, to engage different students in evenly matched competition during the game. The system adopts a competitive race game with drill and practice of four fundamental operations of arithmetic. The system adaptively adjusts virtual opponent competence and uncertain game factors, the generated numbers for operation, to keep the competition evenly matched for different students. This paper presents the implementation of virtual opponent and adaptation mechanisms of the system.

Keywords: personalized game-based learning system, adaptivity, virtual opponent, evenly matched competition

Introduction

Game-based learning systems engage students in learning activities by applying the capabilities of computer to incorporate learning activity with game format, such as goals, rules, fantasy, challenge, competition, interaction [1-3]. Malone [1] pointed out that motivating environments should be challenging and provides goals which players are uncertain to reach or not to reach. The uncertain outcome can be attained by several ways, such as variable difficulty level determined by opponent skills or randomness. Csikszentmihaly [4] also suggested that challenges of tasks and person's skill should be matched to prevent the person from being anxious or bored. However, students may have different capabilities; therefore, game-based learning systems need to be personalized for different students. Personalization can be addressed by adaptablity or adaptivity [5]. To be challenging for different students, Chou and his colleagues design a game-based learning system with adaptable difficulty level [6]. Cheng and his colleagues proposed an equal opportunity tactic to adaptively pair each student with an opponent with similar ability in competitive educational games for moderating the difference in the opportunity of performing well between more-able and less-able students [7]. However, opponents with similar ability may be unavailable. This paper presents a personalized game-based learning system to engage students in evenly matched competition by adaptively adjusting virtual opponent competence and uncertain game factors according to the student game status.

1. ArithmeticWinner: An Personalized Game-based Learning System

A personalized game-based learning system, named ArithmeticWinner, was implemented to engage students in evenly matched competition. The section presents the system, including game based learning activities, implementation of the virtual opponent, and the personalized adaptation mechanisms for keeping evenly matched competition.

1.1 Game based Learning Activities

ArithmeticWinner adopts the game format of WEST [8], which incorporates a racing game with drill and practice of four fundamental operations of arithmetic. In ArithmeticWinner, two players compete to first reach the goal by moving by turns (Figure 1). A player is a virtual opponent and the other player is a student. In a player's turn, the player will get three numbers and need to choose two operators from "+", "-", "×", and "/" operators to compose an arithmetic expression, such as "1+2×3". Each number should be used exactly once in the expression. An operator can be used twice in the expression, such as "1+2+3". Thus there are 96 (3×2×1×4×4) possible expressions. The calculation result of the expression determines the move of the player. If the result was six, the player will move forward six steps. There are three special rules to affect the player's move. First, when a player moves to a castle, the player will jump to the next castle. Second, when a player moves to the beginning of a shortcut, the player will jump to the end of the shortcut. There are three shortcuts, which are from 6 to 15, from 23 to 36, and from 47 to 55. Third, when a player moves to the location of the other player, the other player will be "bumped" and be moved backward ten steps. These special rules make the game more fun and variable, because it might not be best to attain maximum calculation result of three numbers. For instance, a student is at location eight and gets number 1, 2, and 3. Arithmetic expression of "1+2×3" can get the maximum calculation result and make the student move forward seven steps to reach location 15. However, arithmetic expression of "3+1-2" can make the student move forward two steps to reach location ten and jump to location 20 according to the castle special rule. Therefore, students need to explore and compare possible combinations of numbers and operators to attain the best move.

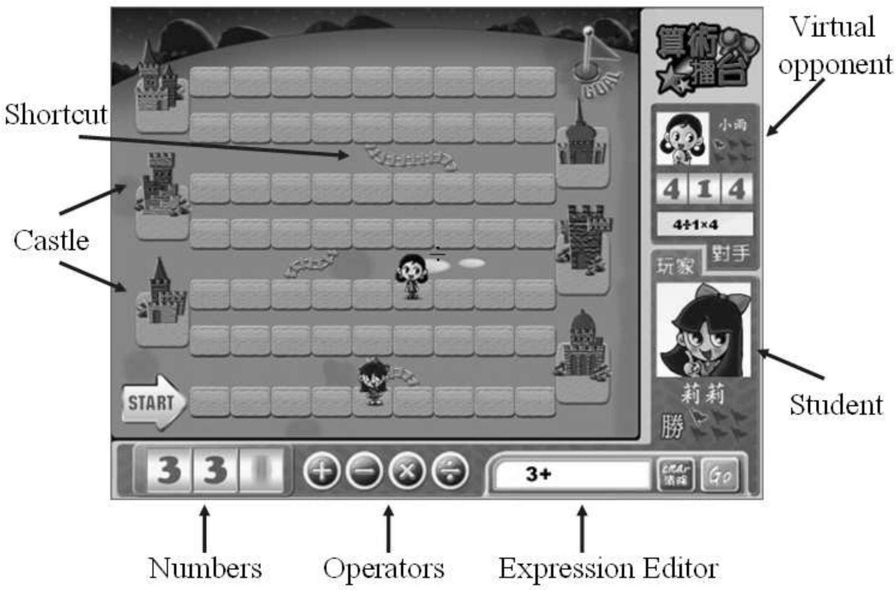

Figure. 1. Screenshot of ArithmeticWinner

1.2 Implementation of Virtual Opponent

The main implementation of virtual opponent is to simulate how the virtual opponent composes expression in its turn. When a player gets three numbers, there are 96 possible expressions. The system calculates the results of all possible expressions and the corresponding arrived location after moving. After calculations, all expressions are sorted by arrived location from minimum to maximum. The expression with maximum arrived location is the best move in this turn. The system chooses appropriate expression from all possible expressions according to virtual opponent competence level to simulate the opponent's expression [9]. The virtual opponent composition is determined by an opponent competence level, which is assigned in advanced and may be adaptively modified during the game. The level is a decimal, which ranges between zero (novice) and one (expert). For instance, if the opponent competence level is one, the component chooses the 96th (96 × 1) expression in the sorted expressions as the opponent's expression; that is, the expression with maximum arrived location. If the opponent competence level is 0.5, the component chooses the 48th (96 × 0.5) expression as the opponent's expression.

1.3 Adaptation Mechanisms for Keeping Evenly Matched Competition

ArithmeticWinner employs two adapting strategies to keep evenly matched competition:

- Keeping evenly matched game progress: Evenly matched game progress indicates that there is no significant difference in player performance between players during the game. If a player was far ahead of the other player during the game, the leading player might feel bored and the other player might feel anxious or depressed. The strategy is to keep the game result uncertain until the last moment. Each player has opportunity to win, but is unsure whether he/she will win or not. The evenly matched game progress and uncertain result may make students feel challenging and excited.
- Maintaining evenly matched game results: Even players are matched, it is also possible that a player always defeats the other player. The always-losing player might feel depressed. The strategy is to maintain game results within an appropriate range; that is, allowing each player to win in some rounds to attain a sense of achievement, and to lose in some rounds to make the player feel challenging and willing to engage in next round to defeat the opponent. Evenly matched game results might depend on the individual personality of students. Some students are self-confident or adventurous and loses may encourage them to make more efforts. On the other hand, some students are less self-confident and need more wins to encourage them. Thus evenly matched game results could be planned as a range and might be adjusted according to student's individual personality.

While an adaptation is required according to the strategies, there are many possible adapting methods, such as adjusting complexity of learning tasks, goals, or even rules. In order not to be easily perceived by students, ArithmeticWinner adopts two adapting methods to realize the strategies:

- Adjusting virtual opponent competence: The competence of virtual opponents can be adjusted to reduce the distance of players. If a student is far ahead of the virtual opponent, the method increases the virtual opponent competence so that the opponent can perform better to catch up with the student. In contrast, the method decreases the virtual opponent competence to allow the student to catch up.
- Adjusting uncertain game factors: Many games have uncertain factors to make the game fun, such as dice, cards. The uncertain game factor in ArithmeticWinner is three numbers which players get. The ArithmeticWinner randomly generates three numbers, which the maximum move of the three numbers does not exceed a move threshold, i.e. 20 moves. If a player is far behind, the system increases the move

threshold of the player so that the player may get the numbers to move further to catch up or even to win. If a player is far ahead, the system decreases the move threshold of the player. If a player is near to the goal and the system prevents the player from winning this round according to the strategy of maintaining evenly matched game results, the system will not provide the numbers which can reach the goal.

2. Summary

This paper proposes evenly matched competition strategies, which adaptively keep students in evenly matched competition game progress and game results in game-based learning. This paper also presents a personalized game-based learning system, which was implemented based on the strategies. To realize the strategies, the system adopts two adapting methods: adjusting virtual opponent competence and adjusting uncertain game factors, that is, the generated numbers for operations. If the student is far behind, the system will decrease the virtual opponent competence and provide numbers to favor the student. The adapting methods can be applied alone or simultaneously. However, the adjustment should be hidden and unperceived by players. Otherwise, players may feel being cheated and refuse to play again or to make effort. We will recruit students to use the system to evaluate whether the system keeps competition evenly matched for students with different capabilities.

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