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Dynamic difficulty adjusting strategy for a two-player video game

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Abstract

This paper describes the progress in implementing an adaptive difficulty strategy in a two-player game, which has been programmed in C, using the SDL graphic library. The selected game mechanics are similar to those of a tank game, which have been replicated many times before. In this case, the game conditions change depending on the players' proficiency, so that both players find a challenge suited to their capabilities, regardless of their skills. This adjustment aims to provide players with a more fulfilling social experience through videogames.

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Keywords: Flow; Dynamic Difficulty Adjustment; Simple DirectMediaLayer; Video Games; Two-Player Balancing.

1. Introduction

Although video games have had a bad reputation almost since their beginnings and are often seen as a waste of time, a negative influence [1][2], or even a health risk, none of these features is part of what we might call the "essence" of a video game. On the subject of gaming and entertainment, Aristotle [3] states that "we need relaxation because we cannot continuously exert ourselves" and this casual relaxation is also necessary to work thoroughly. Thomas Aquinas [4] adds that "Austerity, as a virtue, does not exclude all pleasures, but only such as are excessive and inordinate", the absence of this virtue is the main cause of many problems commonly associated with video games.

While there is no consensus on the definition of video games, common features can be observed among different descriptions set forth in academic literature on the topic. Huizinga [5] reduces the characteristics of play to three: it is a voluntary activity, clearly distinct from ordinary life, and developed within certain limits of time and space. Moreover, the same sociologist poses play in its most primitive form as source of human civilization and its basic institutions.

Other authors, with a more pragmatic approach mention further characteristics, but most of all, they emphasize the potential benefits of games on society. Namely, McGonigal [6] points out, among many other positive qualities, the socializing power of video games, powered by internet connectivity, but not limited to online games. Certain games can motivate a person to interact with others, even when she's more interested in enjoying the game than meeting people, but achieving both objectives at once.

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In order to achieve a game with these properties, it is necessary to find a way to provide a rewarding experience for two or more simultaneous players. In turn, this requires a certain knowledge of what constitutes such an experience.

Psychologist Mihaly Csikszentmihalyi [7] provides an adequate theoretical basis for this problem through the concept of flow. We can roughly define flow as the psychological state in which someone enjoys a performed activity while being deeply concentrated on it as a result of certain conditions: having a clear goal, constant feedback and a challenge that pushes his abilities to the limit. Thus, providing the player with an enjoyable and absorbing experience through a game requires adjusting its difficulty to fit the player's ability. In this manner, the player will face a challenge that is not hard enough to make him feel frustrated, nor too easy, so that he gets bored, taking into account that his skill improves with practice.

This leads to what is known as Dynamic Difficulty Adjustment (DDA), a concept that has been studied by game designers in recent years. The first arcade game machines had already implemented difficulty adjustments to encourage the player to insert more coins by preventing boredom and frustration. However, these early systems had to be consciously activated by the player, and could not rely on an accurate way to adapt themselves.

1.1. Dynamic Difficulty Adjustment

Manually adapting difficulty, or doing it from the beginning of the game may pose serious problems regarding player's perception. Hunicke [8] talks about the importance of carrying out these adjustments in a way that is imperceptible for the user.

In DDA algorithms, two functions are implemented: one that evaluates the player's performance, and another one that adjusts a set of game variables to regulate difficulty. Both of them act dynamically, i.e. operate while the game is running and make the necessary changes with the frequency previously determined by the programmer. Sejrsgaard-Jacobsen et al. [9] recount several DDA algorithms developed by various researchers. However, besides research by Ibáñez and Delgado-Mata [10], writings on the subject of DDA for several-player video games are still scarce.

In this particular case, designers have less control over the game, since they cannot directly influence player's decisions. That's the reason why the aforementioned algorithms should be modified or substituted for our research. The purpose of this paper is to take a generic type of game where two players face each other, and implement a suitable algorithm that leads them to a state of flow.

1.2. Libraries

Programming the graphic routines required for a video game poses a number of problems that are beyond the scope of this work. Therefore, we use a library, which means a set of pre-programmed functions that can be integrated within an independent program. In this case, these routines or functions are used to play sounds, obtain information from various devices, and display images on a computer screen, among other common operations in video game programming.

1.3. SDL

SDL is the acronym for Simple DirectMedia Layer [11][12], a freeware library for 2D game programming that besides being easy to implement, has been successfully used in many commercial video games. It is also cross-platform and supports various programming languages such as Java and C. The latter was used to program the game associated with this work.

2. Development

In the chosen game genre, two characters (usually tanks, but they can be substituted by any other character) move freely in a maze-like setting and try to shoot each other. Any player who is first hit a certain number of times, loses the game. The setting includes several solid blocks, which limit the characters' movements and reduce the chance of an accurate shot. At the bottom of the screen, an image is displayed which gradually fades depending on the number of hits received (Fig. 1). When this image disappears completely, the player loses a "life", and the number of lives is displayed on the screen as well. When all of the lives are depleted, the other player wins.

Fig. 1. Game screen

The variables used to determine which player is taking advantage are the differences between both players in the number of shots received *(1)* and in the time elapsed since the last successful shot *(2)*.

$$\Delta Hits = Hits_{p1} - Hits_{p2} \quad (1)$$

$$\Delta Time = T\_Last\_Hit_{p1} - T\_Last\_Hit_{p2} \quad (2)$$

During the game, each of these two variables is controlled by means of a simple PID system[13]. In both cases, the set point is fixed to zero, which would be an ideal condition for a perfectly balanced game. The resulting output of these controllers are two variables: *dmg* is the number of hit points subtracted every time a bullet hits, from a total of 255 for each character and *mov* is the character speed in pixels per cycle (each cycle lasts about 20ms). Thus, if it takes a long time for a player to hit his target, that same player will move faster, thereby improving his chances of achieving a hit, and if the player has connected a small number of hits, the damage inflicted to the other player by his bullets is incremented. These variables affect the game dynamics (the process in Fig. 2) in such a way that *ΔHits* and *ΔTime* are immediately modified, closing the control loop.

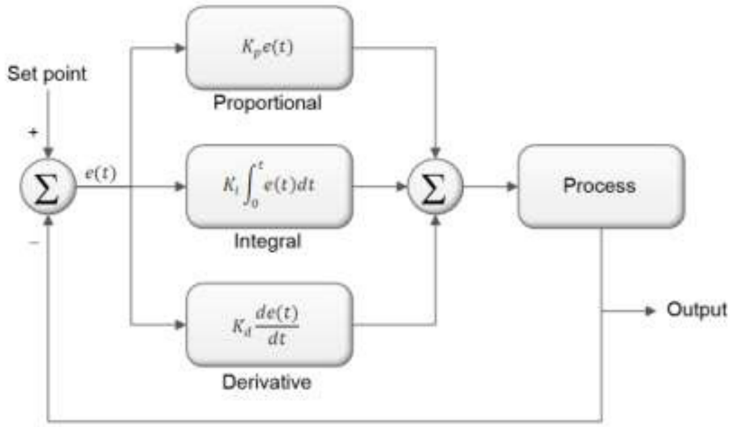

Fig. 2. Common arrangement for a PID controller

3. Methodology

Twenty six volunteers completed a brief questionnaire that subjectively qualified their ability to video games in general. After that, a couple of these volunteers was selected so that there was a significant difference in skill between them, in order to let the adjusting system work, for if a match is naturally balanced, the adjusting system would not be activated.

The participants played a match and answered another questionnaire to assess their level of boredom or frustration afterwards. Then they would play another match and answer the same questionnaire again. In one of the matches (players never knew which) the adjustment system was active, and suppressed in the other. Also, for each match, the program recorded within a file any changes in the variables previously listed.

4. Implementation

Essentially, the program consists of a main loop that is repeated several times per second. Broadly speaking, it performs the following actions.

- Read the keyboard and / or joysticks.
- Change all sprites' positions (bullets and characters).
- Check collisions.
- Modify player scores.
- Evaluate player performance.
- Adjust game features to favor the least skilled player.
- Display images.

5. Preliminary results

From the thirteen pairs of players who participated in the experiment, there were two sets of data. The first represents the subjective evaluation of the game as made by the participants, while the other includes all metrics provided automatically by the software. For subjective appreciation measurements, a 7-point Likert scale [14] was used. Each player evaluated four variables: level of difficulty, frustration, boredom and intention to play again.

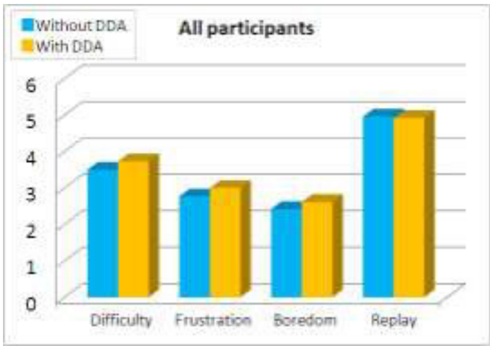

Fig. 3. Results for all participants

The graph shown (Fig. 3) displays the results of the subjective appreciation measurements for all participants. Contrary to expectations, increased difficulty, frustration and boredom were reported.

A similar comparison was made for two different sets of participants, regarding the subjective perception of their own skill: experts and novices.

Expectations were that when introducing dynamic adjustment, the more experienced players would feel less bored, which is congruent with what is shown in (Fig. 4a). Also, the graph shows that the dynamically balanced game makes them feel greater difficulty, frustration and lack of interest for the game.

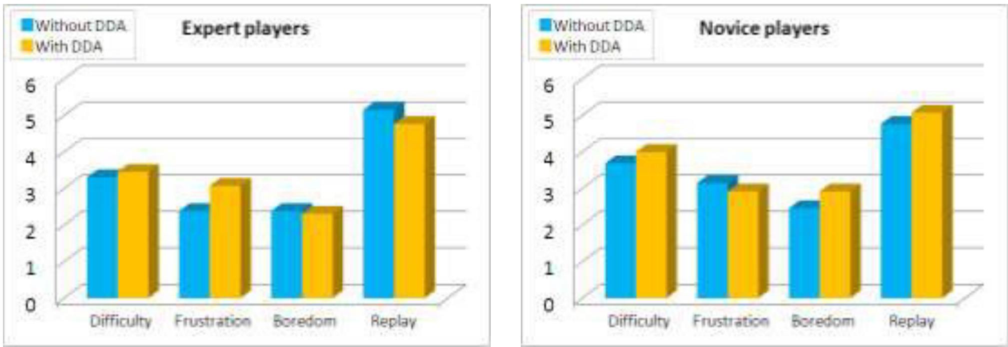

Fig. 4.(a) Results for expert players; (b) Results for novice players

For players with less experience or ability, a decrease in the level of frustration is shown (Fig. 4b) and more interest in the game, yet they seem to feel more bored. This group also felt that the level of difficulty increased, which does not necessarily invalidate the algorithm, since its effects must remain hidden to users.

Nevertheless, data automatically saved by the program shows clearer differences when the DDA algorithm was applied. For example, (Fig. 5) shows two graphs. The one in red describes the modifications applied to variable *dmg* over time by the controller, whereas the blue one shows the effect of these changes on variable *ΔHits*.

It can be seen that in the first game (up to cycle 97), with no DDA algorithm, the difference between the two players is huge, while in the second game, a better balance is achieved when the controller acts directly over *dmg*, and indirectly over *ΔHits*.

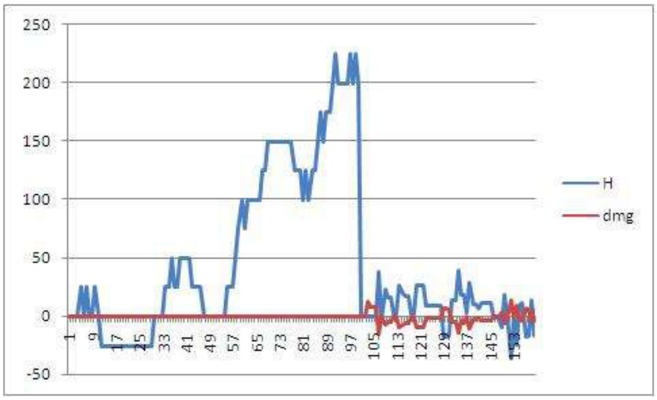

Fig. 5. Example graph for automatically recorded results

The aforementioned graph describes only one game out of the thirteen that constitute the whole experiment. In order to have a better idea of the controller effects in every game, average values were calculated for *ΔHits* and *ΔTime* (Table 1). In average, difference in hit points tends to be smaller, and sometimes favour the other player when the DDA algorithm is working. Hit time differences don't seem to be so sensibly altered, though.

Game	*ΔHits (points)*		*ΔTime (seconds)*	
	without DDA	**with DDA**	**without DDA**	**with DDA**
1	101.15	59.20	-0.60	-3.94
2	79.95	-19.24	1.15	1.41
3	-100.71	5.65	1.39	1.39
4	-79.38	0.68	0.88	-0.71
5	-231.44	-97.58	2.70	3.19
6	64.00	6.67	-0.07	0.05
7	128.31	71.99	-3.07	-5.42
8	-81.19	6.74	1.53	-0.29
9	-40.18	4.91	1.75	-0.95
10	57.84	-7.97	1.07	1.71
11	84.55	41.96	-2.50	-2.41
12	141.24	4.19	-7.66	-2.26
13	-156.95	-13.65	3.69	1.97

Table 1. Average values for *ΔHits* and *ΔTime*

6. Conclusions

In terms of the *ΔHits* variable, a sharp contrast can be appreciated by applying the adjustment algorithm. However, the PID controller associated with the variable *ΔTime* does not seem to have an impact large enough to be taken into account. The change in the variables measuring subjective appreciation of the players is not conclusive. A Wilcoxon [15] signed-rank test to these variables did not yield a sufficient degree of reliability to consider that the averages of both sets (with and without DDA) are not equal for statistical purposes.

It seems necessary to perform a greater number of experiments, adjusting the constants associated with *ΔTime* to have a greater influence, and possibly conducting experiments where *ΔHits* and *ΔTime* adjustments are disabled separately to better appreciate their individual effects. It may also be useful to have couples with higher contrast of skills to participate in the experiment, for example by making the most skilled player become familiar with the game beforehand.

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