ADAPTIVE GAME MECHANICS FOR LEARNING PURPOSES
Making Serious Games Playable and Fun

Jonathan Tremblay, Bruno Bouchard and Abdenour Bouzouane
LIARA laboratory
Université du Québec à Chicoutimi, (Québec)(Rolling and Adams, 2003), Canada
555 boul. Université, G7H 2B1

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Abstract: This paper investigates adaptive games mechanics and how to implement them. First, a comprehensive review of existing adaptive models is presented. Next, we propose a new adaptive model, which combines dynamic difficulty adaptation, the player's performance, and adaptive flow. An implementation of these new adaptive mechanics is presented in the form of a simple serious game called *Number to Number Combat*. This game was released freely on the internet in order to be tested by the gaming community. It has shown very promising results that will help us to improve our adaptive model.

1 INTRODUCTION

The video game industry as entertainment provides the player with many different game genres. A player can choose from puzzles to first person shooters (FPS), casual to hardcore, Play Station to PC, etc. These choices are meaningful for the player (Salen and Zimmerman, 2003), they give the player choices about his game experience based on his own abilities and aspirations. Therefore, they enhance the player's immersion in the game and contribute to his desire to play.

In the last few years, video games have also begun to be more than just fun. An increasing amount of scientists (Jiang et al., 2006) and companies are exploring how games can be used as teaching tools (Gee, 2003) or as a rehabilitation platform (Jiang et al., 2006) for cognitively impaired patients, such as Alzheimer's patients. For instance, one may note the recently published game "Brain Age" on Nintendo DS for which the idea is to provide a series of small simple puzzle games making it possible to play a few minutes per day in the aim of "improving brain performance".

This new way of using video games brings a lot of emergent challenges. One of the most important challenges corresponds to designing a game in which the player can make meaningful choices in a serious context. The fact is that currently, in the industry, players cannot make very many meaningful choices in serious games, even though the diversity of types of players in serious gaming is greater than in the entertainment industry.

This diversity of players introduces different skill levels. Serious games lack the luxury of a vast budget. Despite this lack, games should serve every kind of player and every kind of skill. The process of design for serious games needs to adapt the difficulty level of the game to different sets of skills.

In general, the entertainment industry provides different difficulty levels for games: casual, normal, hard (Gilleade and Dix, 2004). This design process does not take into consideration the game semantic mastered by the players or the player who has difficulty where they are not supposed to. The designer has to understand every kind of player playing the game and make sure that the game is enjoyable for all sorts of players.

A designer should concentrate his efforts on the player's experience, instead of trying to anticipate the player's skill level. A serious game should let every kind of player play the game. Casual to hardcore players should learn from the game and enjoy the game. The player's experience is described as an optimal flow (Chen, 2006), which can be defined as a state of total immersion where the challenge should match the player's abilities perfectly. The player's enjoyment is closely linked to the appropriate level of difficulty. If the challenge

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is too hard, the player will suffer anxiety. On the other hand, if the challenge is too easy, the player will experience boredom. As Juul (Juul, 2009) points out, the player needs to experience failure and difficulty in order to enjoy the game. A game where the player is winning all the time is no fun and the opposite is also not enjoyable. When flow is experienced, the player feels control over the game, they are mastering it. Mastering the semantics of a serious game will lead to mastering the subject of the game (Gee, 2003). Would it be possible for a serious game to allow players to experience flow? If so, would it be possible for serious games to adapt the difficulty of the challenges to the player's skill level?

This research investigates the possible ways for games to adapt to the player's skills and how to implement this adaptation. We found four mainstream adaptive game mechanics: Dynamic Difficulty Adaptation (DDA) (Hunicke, 2005), adaptive flow (Chen, 2006), Game Play Schemas (Lindley and Sennersten, 2008) and using frustration (Gilleade and Dix, 2004). After having reviewed each of them, we developed a new adaptive model which combines feedback (Salen and Zimmerman, 2003) based on DDA, the player's performance, and includes adaptive flow. We implemented these new mechanics into a simple serious game called *Number to Number Combat*, which was released freely on the internet in order to be tested by the gaming community. This game is made so that a frequent player will be challenged more than a casual one. The results obtained after a first testing phase are encouraging and will help us to improve the adaptive model.

The rest of this document is organized as follows: Section 2 discusses previous works related to this research. Section 3 describes our approach to designing our game, our implementation and some early results. Section 4 summarizes our conclusions and presents possible future work.

2 RELATED WORK

The level of difficulty in a game is created linearly by a designer. The design process depends upon play testing, so that the designer can understand the difficulty and tweak the game for a particular kind of player (Chen, 2006). The designer needs to repeat this step until the game is balanced. This is even more time consuming when catering to every kind of player (casual, normal, hardcore, etc.). In reality, when developing a serious game with a low budget, the designer does not have all the time he/she needs to tweak the game perfectly. Introducing adaptive game mechanics makes the game more accessible and enjoyable for the player. It makes the game more challenging for any kind of player, therefore more enjoyable and playable for the player (Juul, 2009). Adaptive game mechanics also require tweaking (Hunicke, 2005). In the last few years, researchers (Hunicke and Chapman, 2004, Chen, 2006, Lindley and Sennersten, 2008, Gilleade and Dix, 2004) have explored different avenues to implement this kind of adaptive mechanics. These sources explain the player's experience using flow theory. We can distinguish four proposed approaches: Dynamic Difficulty Adaptation, Adaptive Flow, Game Play Schemas and using frustration.

2.1 Dynamic Difficulty Adaptation

Dynamic Difficulty Adaptation (DDA) offers alternative-modulating in-game systems to respond to a particular player's abilities over the course of a game session. DDA is based on the mathematical analysis of structures and relationships within a game system (Hunicke, 2005) and on the player's flow experience. DDA uses the flow principle in order to keep the game intriguing and enjoyable. With the right structure, everything from narrative structure to the game menu can possible adjusted (Mateas, 2002). It is very important to completely understand the design and how the system could interact with the game in order to challenge the player.

DDA uses a system that changes the game mechanics without the player knowing it. These changes are made in order to keep the player challenged and interested (Hunicke and Chapman). First, the system computes the player's data; player's position, player's health, player's ammo, etc. Following the system assessment, the system chooses the data that reflects the player's state of flow. The system analyses the player's state of flow and notifies the game of any changes. Lastly, the game apply the changes (Chen, 2006).

For instance when the player is playing a first person shooter (FPS), the system could notice if he/she has low health. The game could be too difficult for the player's skills. The system then could decide to make a health pack available to the player. An important element would be to ensure that the player does not know about systems such as the DDA (Hunicke, 2005).

The system analyses the player's data based on the player's flow experience. However, one of the major problems with DDA is that the system bases its decisions on the player's flow state using only raw data. The raw data used represents the performance of the player, which is objective, while flow is subjective (Chen, 2006) . On the other hand, DDA is straight forward to implement and understand (Hunicke and Chapman, 2004).

2.2 Adaptive Flow

Chen (Chen, 2006) introduces flow as a design process. Based on the assumption that the player's flow experience is subjective, Chen (Chen, 2006) proposes giving the player control. Control is a requirement for the flow experience, the player must feel in control over his/her actions in order to experience flow (Salen and Zimmerman, 2003). The sense of control comes from the sense of progression and positive feedback (Chen, 2006). In the design of the game, the player should control the level of difficulty. Figure 1 shows how a player can make choices that can result in changing his flow experience.

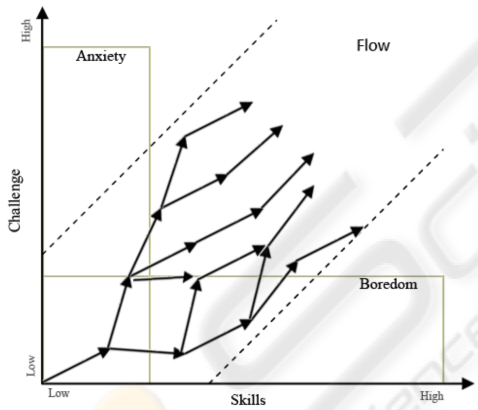

Figure 1: Adaptive flow based on player's choices.

In order to design such a game, the designer needs to include a wide spectrum of game mechanics for a variety of levels of difficulty and tastes. The game should provide a player-oriented active DDA to allow different players to play at their own pace. This system must be embedded in the game core mechanics and let the player make their own choices through play (Chen, 2006). For instance, the player could experience an intense challenge or choose to explore and power up his avatar which will attenuate the challenge's intensity.

Designing a game with embedded meaningful choices regarding the difficulty of play is not a simple task. The designer has to think of the game as a DDA platform from the beginning. Should the game already exist, it is almost impossible to include adaptive flow after the fact.

2.3 Game Play Schemas

Lindley and Sennersten (Lindley and Sennersten, 2008) introduce game mechanics based on schema theory. A schema is a semantic representation of knowledge integrated into the decision process. Schema applied to game mechanics becomes an algorithm representation of the semantic knowledge needed to perform an action within the game. Therefore, the player's actions can be reproduced as an algorithm.

Example of a schema game mechanics algorithm for a typical adventure game:

```
if(player.sick)
   player.getHeal();
else
   player.Attack();
```

This algorithm is typical in adventure, before attacking we check if the avatar is sick. Based on the data, the player's action consists of either attacking or healing. Using this algorithm a system could find where a player makes mistakes during play. In this case, if the player never heals his avatar; this could indicate that the player does not understand the meaning of being sick. With this mistake found, the system could intercept in order to help the player. This help could be meaningful for a casual player, such as Alzheimer's patient.

In other situations, a schema game play could be used to adapt the game to the player's style (Lindley and Sennersten, 2008). The system, by determining what type of player is playing, can introduce elements that the player enjoys based on the player's repetitive actions such as how the player is defeating None Player Character (NPC), how the player is driving his car, how the player interacts with the menu, etc.

A major issue with the game play schemas' model is that it has never been implemented or tested (Lindley and Sennersten, 2008). Moreover, it seems that it would be very time consuming to implement. In order to understand the player's interaction with the game, the designer would need a lot of case studies and would have to calculate the possible mistakes a player may make.

2.4 Using Frustration

Frustration in a game is something that every player has experienced at least once. Frustration arises when the in-game progress towards achievement is impeded (Gilleade and Dix, 2004). When the player is unable to complete a command, he/she becomes frustrated as he/she is not able to progress. Furthermore, the player becomes frustrated when he/she cannot complete a certain challenge in the game due to a misunderstanding of the game challenge.

Using DDA, when the player is getting frustrated, the system could change the game difficulty or provide help to the player. For example, the game system could change the width of a hole the player had fallen into so that their next attempt at jumping over the hole would be successful and the player would be less frustrated.

The major issue with this model is the detection of frustration. Frustration can be measured using blood pressure, heart rate and conductivity (Gilleade and Dix, 2004). These measurements are related to the level of arousal. From a commercial point of view, using these measurements is almost impossible; the only existing connection between the player and the game is the gamepad. Some research (Sykes and Brown, 2003) indicates that it is possible to measure the player's level of arousal by monitoring button pressure on the gamepad. However, this idea has never really been officially used as an adaptive mechanic.

3 IMPLEMENTATION AND RESULTS

We have developed a digital learning game prototype called *Number to Number Combat* to use as an experimental test for our research in adaptive game mechanics. A screenshot of the game is shown in Figure 2. *Number to Number Combat* is a game that is designed to teach and master basic arithmetic; addition and subtraction.

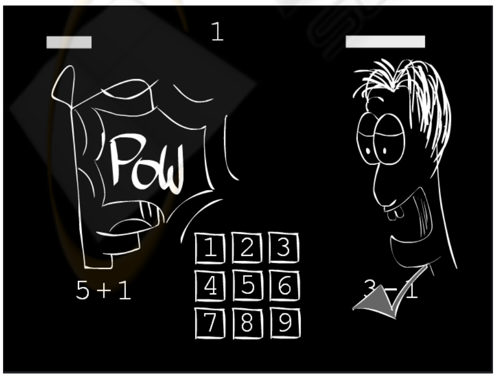

Figure 2: Screenshot of *Number to Number Combat* game.

The current version of *Number to Number Combat* is simple; there is no end to the game. The player is playing the left avatar, by answering correctly the equation; the avatar will hit his opponent and inflict damage. On the other side, the NPC will randomly hit the player. The goal is to defeat the NPC before it defeats you. When the player wins, he/she has to build up his/her avatar's force, defence and luck. Force gives the player more powerful hits. Defence protects the player from his opponent. Luck increases the player's chances of hitting a weak spot.

3.1 Adaptive Game Mechanics

In *Number to Number Combat*, we propose a new adaptive model which combines feedback (Salen and Zimmerman, 2003) based on DDA as well as the player's performance, and includes adaptive flow. The DDA system is based on the player's health. As represented in Figure 3, when the player finishes a combat with a low health bar, the next opponent will be easier to vanquish. On the other hand, when the player is mastering a combat and his/her health bar is full, the next opponent will be a little harder. The system works without the player noticing. The way the system changes the NPC difficulty is by feedback. The system uses negative feedback, that consists of reducing the gap between two related elements (Salen and Zimmerman, 2003). In other words, if the challenge is too hard for the player, the negative feedback will reduce the difficulty of the gap.

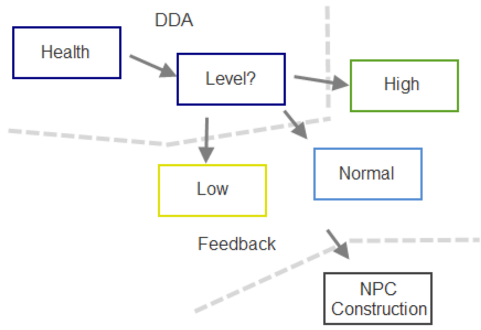

Figure 3: DDA using negative feedback in Number to Number Combat.

After a fight, the player must choose what he will put the 2 points he has earned towards. This is adaptive flow at work. This part maps the kind of fight the player will encounter. If a player adds a lot of points to their Strength, the fights will need a fast paced answer entry. On the other hand, if the player adds a lot of points towards his Defence, the fights will be slower, and both the player and the NPC will be well protected against attacks. Finally, if the player adds a lot of Luck, the fights will be completely random.

3.2 Validation and Results

We proceeded to a first validation phase for our new adaptive approach by releasing *Number to Number Combat* as Freeware on the website www.newgrounds.com. Newgrounds provides a free online video game platform for independent developers. There are about 2 million registered members and 500 000 flash submissions (Fulp, 2010). Players can comment on the game and rank it. Since the game came out, it has been played by over a thousand players. The results obtained so far are very promising, knowing that, even if this serious game is very basic and simple, the players' average review is 8.2/10 and the game received very positive comments. One of the aspects of the game most appreciated by the players is that the game improves theirs math skills with basic arithmetic in an enjoyable combat role playing game world. We believe that the new adaptive mechanics included in the game contributed to the great appreciation from the players.

Conversely, some players were disappointed that the game does not get harder after a certain time. Also, the aesthetic aspect of the game does not seem to be appealing enough for the players and the fights are too repetitive and do not offer enough sense of control over the avatar. Finally, the role playing elements do not seem to make a difference in the game experience. Implementing a more complex game system with more attractive graphics and more controls will help us to alleviate these concerns and to conduct enriching further tests on the adaptive model.

4 CONCLUSIONS AND FUTURE WORK

In this paper, we investigated adaptive mechanics in games and how to implement them. This has been achieved by reviewing existing adaptive models, by proposing a new adaptive approach combining dynamic difficulty adaptation, the player's performance, and adaptive flow, and by presenting an implementation of this new adaptive mechanic in the form of a simple serious game called *Number to Number Combat*. We also presented the promising results of a priliminary validation phase conducted by releasing the game freely on the Internet to be tested by the gaming community.

Every game teaches something about a system (Koster, 2004, Gee, 2003). The preliminary comments gathered by releasing *Number to Number Combat* show promise, but the game is not perfect and has a couple of design flaws. One important element that we bring to light in this paper is that serious games need to be treated like any entertainment game; the game has to be appealing for the player. Therefore, we plan on working on a narrative framework for the game, redoing the graphics and getting the game balanced.

Number to Number Combat was a first step in the LIARA laboratory new project, which aims to give way to video games as a new software platform allowing the support of medical and learning tools, less expensive and more accessible, that will be used, for instance, for palliative care for those suffering from Alzheimer's disease. Using this kind of serious game will be enjoyable, fun, and will make a real difference in the life of Alzheimer's patients by slowing the degenerative process of their disease, thus contributing to giving them a better quality of life (Tárraga et al., 2006). We plan on developing prototype games for Alzheimer's patients, for people suffering from head traumas and for people with other cognitive impairments. The Alzheimer's patients are casual gamers, we need to adapt our design process to make sure the game they play is accessible, fun, and that it answers their needs.

The next logical step in this project consists of implementing our adaptive mechanics in a more complex game system and testing it. We also plan on exploring different adaptive game mechanics such as game play schemas (Lindley and Sennersten, 2008). Implementing these models could help the design process for serious games. Finally, we recently signed a collaborative agreement with the rehabilitation center of La Baie, which is an institution that treats Alzheimer's patients. This will allow us to test our prototype on the targeted audience.

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