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A methodological approach to identifying and quantifying video game difficulty factors ☆

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ABSTRACT

Video games which are unable to identify and adjust the level of difficulty to the player's ability have no mechanism to engage a player who is beginning to become bored or overly frustrated with their gaming experience. Players who are overly bored or frustrated by a game might completely abandon the game; as most players purchase games on the recommendations of other players, this can damage the commercial side of the video game (Bateman and Boon, 2006). Our research formalizes and evaluates a methodology for identifying and quantifying the effects of different game factors on a player's performance. To evaluate our methodology, we have designed an experimental testbed based on the classic video game Pac-Man. The evaluation of player performance is subdivided into response variables based on collecting items, the overall score, and the ability to remain alive. In the testbed, the behavior of Pac-Man and the ghosts is simulated, and every parameter and algorithm within the testbed is capable of being adjusted. Our experiment simulates game sessions for Pac-Man and the ghosts, observing the impact of adjusting the different game factors on the player's performance. The impact of a game factor and its interaction with other factors is evaluated using a full factorial analysis. The results of our analysis identify factors with varying degrees of impact on the player's performance. In doing so, these results identify a small sets of game factors which have a prominent impact on nearly all players, in addition to a unique sets of factors which impact only specific player types.

1. Introduction

Properly identifying the ideal level of game difficulty for an individual is critically important to the success of the game, as it would allow adjustments for new players to slowly engage in the game at their own pace, and could increase the difficulty quickly for more experienced players. Correctly matching the difficulty of a game to the player's abilities does not guarantee it will not be abandoned by the player, as a player may reject a video game for other reasons; such as a lack of interest in the story or the genre. However, the level of difficulty of a video game is consistently listed as one of the most important aspects for it to be considered engaging [2,3].

The importance of dynamically identifying the difficulty of a game and adapting the challenge level to the player's ability is becoming even more important. In recent years, the gaming community has experienced an influx of new player demographics introduced to gaming by the paradigm shift of how players can be actively engaged [1], as well as a surge in popularity of so-called casual games made more accessible through the rise of mobile, web, and social platforms for gaming. The paradigm shift towards non-standard controller systems has further promoted the use of video game systems as tools to support other research areas such education and rehabilitation. As the user demographics of video games expands, so too will the range of player abilities and entertainment needs. Players will have varying levels of experience with interfacing with technology as well as varying skill levels in terms of personal characteristics such as reaction times, hand eye coordination, and tolerance for failure. The variation in players' abilities will increase the difficulty for game designers to sort players into the usual static and preset difficulty settings of easy, medium and hard.

As the applications of video games continue to broaden into other research areas and new demographics of users, the importance of having customized learning, training, and feedback could become critical to the success of the application. To overcome the complexity and effort involved in designing for a significant number and variety of players, there is a growing need to more thoroughly understand game difficulty, especially the impact of

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various factors and design decisions on difficulty and outcomes. To form this understanding, experimental methods are required to collect and analyze the necessary data in a rigorous fashion. This, unfortunately, is a daunting task for any game of reasonable size and complexity. Consequently, the goal of our current work is to formalize an approach to studying game difficulty, in particular identifying prominent factors and determining their impact on player experience. This approach has applications to offline analysis during production to support game balancing, level tuning, and issues with playability and usability. Online applications for adaptive game systems include determining suitable factors and the granularity of adjustments necessary to optimize the player's experience. In this paper, we present our approach, based on a full factorial analysis methodology, and demonstrate its usefulness through applying an experimental assessment to a testbed version of the classic game Pac-Man.

2. Related work

At a high level, an adaptive gaming system includes the following components: player type database, player preference modeler, game performance monitor, and a component to adjust game parameters [4]. The adaptive game system consistently monitors the player's performance then makes adjustments to the game based on the individual's preferences and player type models. After adjusting the game based on the player's individual needs, the adaptive game system continues monitoring to identify if the adjustments had the intended impact on the overall performance of the player. If the player's performance since the adjustments does not match the expectations of the adaptive game system's player model, the player model is tuned from the feedback of this scenario. Our research will explore the adaptive gaming system component that adjusts game parameters and monitors the player's performance.

All dynamic adjustments to the game must be performed with care; if a player identifies that an adaptive difficulty system is controlling the pace of their game play, their sense of achievement for completing difficult tasks can be diminished or extinguished [5]. If the player begins to attribute the result of their game play to external factors, they can become extremely frustrated and can completely lose interest in participation [1].

Adaptive gaming system research demonstrates different methods of adjusting the difficulty of the game. The general areas for performing game adjustments are: the player's character, level design, and the characteristics of non-playable characters (NPC). Adjustments can be performed proactively or retroactively to a difficult situation or task. Proactive adjustments can occur before a task or difficult area of the game is attempted; adjustments can be initiated based on previous success or difficulty with similar areas of the game. Retroactive adjustments occur after a player has began a specific task; the adjustments can occur while the player is still actively participating in the task.

The player's character is one of the most sensitive areas for adjustments to the game, and can be frustrating and intrusive to the player, if incorrectly performed. As the game progresses, players develop an emotional attachment to their character; they can consider them extensions of themselves in the virtual world and, as such, any modifications must be performed with great care as the player may reject any unwanted limitations [1]. However, if adjustments to the player's character are performed correctly, the emotional connection between the player and their avatar can be empowering for the individual as they overcome obstacles. Examples of modifying the player's character include temporarily taking more damage, having slower healing times, or decreased delays between special moves.

Dynamically adjusting the design of a level can occur at a large scale, in which entire levels can be generated, or at a smaller scale, for example modifying the placement of key items within a level. Large scale adjustments can include generating entire new levels based on the player's performance; for example, researchers have developed a game in which new car tracks are generated based on the player's previous performance [6,7]. Level adjustments could be made to smaller portions of the level; as an example in a first-person shooter (FPS), if a player is struggling, the level could be re-designed to include more walls in open areas to protect the player. Redesigning a level at run-time is computationally expensive in terms of game-AI path-finding and planning, as well as for graphics and rendering in areas such as lighting and shadows. Thus, it is more plausible that levels could be separated into multiple sections that are predefined and then recombined before the start of the level based on the player's previous difficulty with other levels. On a smaller scale, the position and value of items can be modified within a level to add variety to gameplay or provide that badly needed item just in time to save a character. One interesting criticism for modifying the position of items is that although the adaptive system can provide that desperately needed item that comes just in time to save the player, it reduces the player's ability to formulate a consistent strategy for a level. The dynamic aspect of item value and placement reduces the player's ability to accurately assess the risk to reward ratio in accomplishing a task.

Non-player characters (NPCs) are characters outside the player's control; they can be allies, enemies, or neutral to your character. Adapting NPC characters can be ideal because the player expects the NPCs to mature throughout the game, increasing in difficulty and developing better strategies. In addition, NPC attribute information and abilities are rarely visible or modifiable by the player; thus, they provide an ideal situation for making dynamic adjustments. As such, the player is more accepting of modifications to the difficulty of the NPCs of the game and less likely to feel cheated by the adaptive game system when adjustments occur. Modifying the behavior and strategies used by the NPC's is another opportunity to perform adjustments and inject variation into the game play. Research for adjusting an NPC's decision process or strategy to maximize player enjoyment use a variety of techniques from machine learning [8,9], to dynamic scripting [10,11].

Research on adaptive NPCs using a machine learning technique generally focuses on minimizing the deviation from a single performance metric, such as score or health. As an example, researchers developed a *Street Fighter* type game, in which two combatants attempt to reduce the other's health to zero. Their research demonstrated the ability to adapt the final result of the game to within 10 health points for both static algorithm combatants and combatants evolved via machine learning [8]. Their research did demonstrate the ability to effectively adapt to different combatants' skill levels, a next logical progression for this research is to expand the player model beyond the one response variable for health points. Using a more complex player model would help determine the logical fluidity of the adaptive decision process and potentially provide richer gameplay experience for the player.

Dynamic scripting uses reinforcement learning techniques to learn context appropriate decisions based on the result of exploratory actions. Using a reward and punishment system, decisions are weighted based on their success or failure against an opponent. Dynamic scripting adjusts the difficulty of the game by providing a ranged subset of all available options determined to be an appropriate to the player's skill level [10,11]. By providing a subset of possible moves, dynamic scripting could control for other important gameplay factors such as variation and unique challenges. One of the challenges for dynamic scripting is developing new actions scripts when none of the previous action scripts match