Creating Model-Based Adaptive Environments Using Game-Specific and Game-Independent Analytics

Brent Harrison
North Carolina State University
Raleigh, North Carolina 27606

Abstract

My research involves creating and evaluating adaptive game environments using player models created with data-driven techniques and algorithms. I hypothesize that I will be able to change parts of a game to elicit certain behaviors from players, and that these changes will also result in an increase of engagement and/or intrinsic motivation. Initial results in my testbed game, *Scrabblesque*, indicate that data-driven models and techniques can be used to influence player behavior and that these changes in play behavior manifest themselves as an increase in engagement and intrinsic motivation.

Introduction

The goal of my research is to show that game analytics can be used to model players and that these models can be used to adapt games to elicit certain types of behavior and create more engaging experiences for players. Based on these goals, the thesis statement for my dissertation is as follows:

Data-driven player models and action generation techniques can be used to dynamically adapt game experiences to influence quantifiably identifiable player behavior which will, in turn, increase player engagement and/or intrinsic motivation without the need for time-intensive hand authoring.

From this thesis statement, I have determined that there are three questions that I must answer.

1. What techniques can be used to create data-driven models of player behavior?

2. How can I use these models of player behavior to alter different game environments to elicit a desired response from the player in real time?

3. Do these changes elicit the desired responses in terms of observable behavior and intrinsic motivation/engagement?

These questions represent the three phases that my research will be performed in: player model construction, game adaptation, and evaluation.

To ensure external validity, I have chosen to study two different game environments of varying complexity. The first is a simple game environment based on the board game *Scrabble* which I have named *Scrabblesque*. The second is a more complex game environment, tentatively named *Sidequest: The Game* (*SQ:TG*), in which the player will complete various quests in order to advance to the end of the game. I have chosen these two environments because they present varying degrees of challenges with respect to handling player interaction and determining how to alter the game world.

Related Work

Since the core of my work concerns player modeling and game adaption, I will give a brief sample of the work done in these fields.

Player Modeling

One technique that is used to generate player models is to use player feedback. These techniques were used by Richard Bartle (1996) and Nick Yee (2006) to determine player types. The models used in the *PaSSAGE* system (Thue, Bulitko, and Spetch 2008) use an author-informed mapping from actions onto predefined player types in order to determine which actions certain users will prefer. The main issue with these techniques is that they rely on imperfect knowledge which can lead to poor model quality. I feel that data-driven techniques address this issue because they use observed behaviors to create player models.

There have been several advancements in the area of data-driven player modeling. Drachen et al. (2009) used self-organizing maps to determine that four classes of players exist in *Tomb-Raider: Underworld* by examining a set of game-specific analytics. Recently, Zook et al. (2012) used matrix factorization to model and predict player performance in training simulations. An overview of player modeling techniques can be found in (Smith et al. 2011).

Game adaptation

Perhaps the most common form of game adaptation is dynamic difficulty adjustment (DDA). An example of using DDA can be found in *Left 4 Dead* (2009). *Left 4 Dead* employs an AI director that controls the number of enemies spawned in order to induce certain responses from the players during gameplay. PaSSAGE (Thue, Bulitko, and Spetch

2008) presents content to a player based on that player's estimated *type* which can be one of the following: fighter, power gamer, tacticians, storytellers, or method actors.

Constructing Player Models

In order to create data-driven player models, I will examine two classes of gameplay analytics: game-specific features and game-independent features. Game-independent features are those that exist in almost every video game, such as features concerning input devices. Game-specific features are those that cannot be separated from the game that they are in. The reason that I have chosen to examine these two classes of features is because I hope to create models that balance descriptive power with the ability to transfer across genres.

For *SQ:TG*, I have explored using correlation networks along with a set of game-specific features to identify sets of quests that are likely to be completed together (Harrison and Roberts 2011) to predict which quests a player is likely to complete. For *Scrabblesque*, I used both game-specific and game-independent features to create a naive Bayesian model to calculate the probability that a player will quit the game prematurely (Harrison and Roberts 2012).

Game adaptation

Once I have these models of human behavior in games, I will develop techniques that use these models to adapt each game in order to elicit certain behavioral responses in players (such as completing more games in *Scrabblesque*). To adapt the game, I will be using an *experience manager* (Riedl et al. 2008). An *experience manager* is an agent that uses a model of player behavior in order to make alterations to the game environment. My experience manager will use a data-driven backwards induction algorithm to choose what adaptations should be made to the game environment.

At a high level, the algorithm works by identifying game states which are likely to induce a desired behavior in the current player and then performing actions to move the current game state closer to the desired game state. Currently, this system has been implemented in *Scrabblesque* with the goal of reducing the number of games players end early.

Evaluation

To determine whether the adaptations made to the game had the desired effect, I will perform evaluations using both game environments. Each of these experiments will be carried out independently of one another. Both of these experiments will be done using a between subjects, classic experimental design with the presence or absence of the experience manager being the independent variable.

The quantitative metrics that I study are determined by the behaviors that I am seeking to inhibit or facilitate. In *Scrabblesque*, for example, I evaluate the number of games that end early because that was the goal of the adaptations made. To qualitatively validate my techniques, I will look at two metrics describing player experience: intrinsic motivation (Ryan and Deci 2000) and player engagement (Brockmyer et al. 2009). I have already evaluated my work in *Scrabblesque*.

Conclusion

By the end of my research, I will have shown that player models can be constructed procedurally by looking at game-specific and game-independent analytics in simple and complex game environments and that these models can be used to create a data-driven experience manager capable of meeting authorial goals and increasing engagement and intrinsic motivation without intensive authoring efforts. Through this work, I expect to make the following contributions:

- Designing algorithms to create models of player behavior using game-specific and game-independent analytics
- Creating methods to adapt various game environments using these models of player behavior
- A qualitative and quantitative evaluation of the adaptations made by my algorithm

References

Bartle, R. 1996. Hearts, clubs, diamonds, spades: Players who suit MUDs. *Journal of MUD research* 1(1):19.

Booth, M. 2009. The ai systems of left 4 dead. In *Keynote, Fifth Artificial Intelligence and Interactive Digital Entertainment Conference (AIIDE09)*.

Brockmyer, J.; Fox, C.; Curtiss, K.; McBroom, E.; Burkhart, K.; and Pidruzny, J. 2009. The development of the game engagement questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology* 45(4):624–634.

Drachen, A.; Canossa, A.; and Yannakakis, G. 2009. Player modeling using self-organization in Tomb Raider: Underworld. In *Computational Intelligence and Games, 2009. CIG 2009. IEEE Symposium on*, 1–8. IEEE.

Harrison, B., and Roberts, D. 2011. Using sequential observations to model and predict player behavior. In *Proceedings of the Sixth International Conference on the Foundations of Digital Games, New York, NY, USA*.

Harrison, B., and Roberts, D. 2012. When players quit (playing scrabble). In *Proceedings of the Eighth Annual AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment*.

Riedl, M.; Stern, A.; Dini, D.; and Alderman, J. 2008. Dynamic experience management in virtual worlds for entertainment, education, and training. *International Transactions on Systems Science and Applications, Special Issue on Agent Based Systems for Human Learning* 4(2):23–42.

Ryan, R., and Deci, E. 2000. Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary educational psychology* 25(1):54–67.

Smith, A.; Lewis, C.; Hullet, K.; and Sullivan, A. 2011. An inclusive view of player modeling. In *Proceedings of the 6th International Conference on Foundations of Digital Games*, 301–303. ACM.

Thue, D.; Bulitko, V.; and Spetch, M. 2008. PaSSAGE: A Demonstration of Player Modeling in Interactive Storytelling. *Artificial Intelligence and Interactive Digital Entertainment (Palo Alto, CA, USA) AIIDE* 8.

Yee, N. 2006. Motivations for play in online games. *CyberPsychology & Behavior* 9(6):772–775.

Zook, A.; Lee-Urban, S.; Drinkwater, M.; and Riedl, M. 2012. Skill-based mission generation: A data-driven temporal player modeling approach. In *Proceedings of the 7th International Conference on Foundations of Digital Games*.