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Player behavior and personality modeling for interactive storytelling in games

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A R T I C L E I N F O

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A B S T R A C T

Current video games use simple methods to deal with interactive narratives and the enormous variety of player types. In this paper, we propose a novel approach to interactive storytelling in games, in which the quests and the ongoing story are determined in view of individual personality traits and behavioral attitudes in a non-deterministic way. Our method starts the process employing a new technique to assess the player's personality traits according to the well-known Big Five model. These traits are then used by a nondeterministic planning algorithm to define adaptive goal hierarchies. In addition, an artificial neural network is trained to predict player behaviors in real-time, allowing partial-order planning operators to use player behaviors and personality traits as logical terms in their preconditions. With this approach, a richer individualized experience is provided to the player, while preserving consistency with the conventions of the chosen genre.

1. Introduction

Video games add new dimensions to traditional storytelling by allowing players to change narratives through their own actions. In modern Role-Playing Games (RPGs), this is usually done by adopting branching storylines based on key choices presented to players at certain points of the game. Some RPGs, such as *Mass Effect 2* (BioWare, 2010), *Dragon Age: Inquisition* (BioWare, 2014), and *The Witcher 3: Wild Hunt* (CD Projekt RED, 2015), perform this so well that they provide the player with a real sense of control over the story. However, such branching points are usually presented through specific dialog choices or predetermined actions (e.g. killing or forgiving an enemy, collecting or not collecting a specific item), which reduces the player's sense of agency (i.e. the impression of controlling his/her own actions).

Currently, both game industry and game consumers have great interest in new forms of interactive storytelling that may provide games with truly interactive stories, in which all in-game player's actions and preferences can affect the development of the narrative. However, understanding player preferences and interpreting in-game behaviors in real-time is not an easy task. This problem involves an active topic of research on artificial intelligence, known as player modeling.

Player modeling is the study and use of artificial and computational intelligence techniques [1] for the construction of computational models of players, which includes cognitive, affective and behavioral characteristics. In general, a player model is an abstract description of the player's characteristics in the real world or in the game environment [2]. Indeed, the construction of effective player models involves a multidisciplinary intersection of the fields of affective computing, experimental psychology, human-computer interaction, big data, and analytics, which are part of the so called "game analytics" [3].

Nowadays, analyzing game data is a common practice widely employed in the game industry to validate level design or improve the player experience [3,4]. Many commercial games are known for adopting player modeling techniques, such as *Silent Hill: Shattered Memories* (Konami, 2009), which dynamically creates personality models of the players and uses them to adapt gameplay elements [5]; *League of Legends* (Riot Games, 2009), which explores the analysis of gameplay data to design new content updates [6]; and *Left 4 Dead* (Valve, 2008), which uses player modeling to adapt the difficulty of the game's challenges in response to the player's actions. Even though player modeling has been successfully applied to commercial games and widely explored by academic researchers, only few works treat the prediction of actual player behavior or the use of this information to create interactive game narratives.

We consider actual player behavior to be the way in which the player acts or conducts him or herself in the game. For instance, the player may behave aggressively, impulsively, or cautiously when facing dangerous situations. Behavior, in general, is not only complex, but also

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dynamic. A behavioral description for one occasion is likely to be invalid for another occasion. In fact, behavior is susceptible to variation in consequence of any change in time, place, emotion, and social context [7]. In addition, a player's behavior within a game environment may be very different from the same person's behavior when dealing with real world situations.

Although understanding player behavior can help games to adapt their narratives as an indirect consequence of the players' actions, there is no guarantee that they will enjoy the resulting narratives. An important factor to be considered when adapting game narratives is the personality of the players, which is known to exert a major influence on their preferences and expectations for future narrative events [8]. When a game is aimed at providing pleasurable entertainment, having some information about the current player's preferences is vital to create satisfying playing experiences.

In this paper, we propose a novel approach to interactive storytelling in games based on player behavior and personality modeling, hierarchical task decomposition and nondeterministic planning.[1] The proposed method can generate dynamic and nondeterministic hierarchical quests[2] that are directly or indirectly affected by the player's *personality* and *in-game behavior*, which are both modeled in terms of the Big Five factors [9]. These factors are typically used to describe individual personality, but they can also be used to explain human behaviors [40,41].

Before the game starts, our method uses a new technique to find the player's *personality traits* based on the Big Five model. These traits are used by the nondeterministic planning algorithm to define goal hierarchies during gameplay. Also we define behavioral aspects based on Big Five factors, which are associated with general in-game *player behaviors*. In our method we use an artificial neural network to predict behavioral aspects based on 32 statistical features extracted from the gameplay. Once the neural network is trained, the system can predict player behaviors at any time. After the game starts, *partial-order planning operators* take the following characteristics as terms of its *preconditions*: player behaviors (which are dynamic and time dependent) and personality traits (which are "persisting" characteristics that are consistently demonstrated despite changing circumstances or game environment).

The above-mentioned new technique to determine the player's personality traits uses a preliminary short session with story-related scenes, which are based on the 10-item Big Five inventory called BFI-10 [48]. For the sake of concisely presenting our method, we name this technique as *Big Five Game Inventory* (BFGI-10).

In this paper, we evaluate the following elements of our approach to interactive storytelling in games: the behavioral model (by assessing the accuracy and performance of the Neural Network); the personality model (by comparing the results of our Big Five Game Inventory and BFI-10); and the hierarchical quest generation algorithm (by analyzing its scalability and performance). Since in our project we take for granted the desirability of player modeling features in games, provided that they are well-calibrated and, in addition, do not raise privacy concerns, we did not propose to compare the users' reactions to game versions with and without such features.

The paper is organized as follows. Section 2 reviews related work. Section 3 gives an overview of the system architecture and introduces the testbed game used to validate our method. Section 4 presents the proposed player behavior model. Section 5 describes the proposed personality model. Section 6 presents the proposed method for quest generation based on nondeterministic planning and player modeling. Section 7 contains an evaluation of our method. Section 8 offers concluding remarks.

[1] We use the term "nondeterministic planning" for planning problems in which the planning domain is a nondeterministic state-transition system, i.e. an action may have more than one possible outcome [10],[11].

[2] Quests are missions or objectives to be accomplished by *avatars* (which are game characters controlled by human players).

2. Related work

There are several works on player modeling in the literature, which started with the concept of player types. Indeed, one of the earliest attempts to create player models came in 1996 when Richard Bartle [12] proposed his four player types (Achievers, Socializers, Explorers, and Killers). Following Bartle's work, Bateman and Boon [13] created another model using the Myers-Briggs personality indicator [14] to categorized players into four classes: Conqueror, Manager, Wanderer and Participant. Yee [15] empirically grounded Bartle's original model and found that player motivation has three main components: achievement, social, and immersion. Moreover, taking inspiration from neurobiological research, Nacke et al. [16] proposed seven player archetypes (Seeker, Survivor, Daredevil, Mastermind, Conqueror, Socializer, Achiever). However, as previously pointed by Tuunanen and Hamari [17], type-based approaches are very limited, because types provide only a superficial information about the player, which can be even more blurred considering that most players cannot be adequately categorized into a single group.

In recent years there have been several successful implementations of player modeling in games, whose applications include the use of player models for adapting player experience, game balancing, personalized content generation, playtesting analysis and game authoring. Missura and Gärtner [18] explore the use of clustering and classification techniques to dynamically adjust the difficulty of a shooter game. Their method uses k-means and support vector machines to classify players into different types based on gameplay data. Weber and Mateas [19] employ a series of classification algorithms for recognizing player strategies in *StarCraft* (Blizzard Entertainment, 1998). Mahlman et al. [20] use several supervised machine learning algorithms, trained with a set of player behavior data extracted from the game *Tomb Raider: Underworld* (Crystal Dynamics, 2008), in order to predict when a player will stop playing the game and, if the player completes the game, how long will it take to do so. Machado et al. [21] and Spronck and den Teuling [22] explore player modeling in the context of the game *Civilization IV* (Firaxis Games, 2005). Machado et al. [op. cit.] create models of virtual agent's preferences using classifiers based on support vector machines, and Spronck and den Teuling [op. cit.] use a sequential minimal optimization (SMO) classifier to build a player model to predict specific preference values. In a recent work, Valls-Vargas et al. [4] propose a player modeling framework to capture and predict play style using episodic segmentation of gameplay traces and sequential machine learning techniques. Their framework utilizes multiple models that include predictions from previous time intervals to identify how players change play style over time.

The use of player modeling has also been explored in interactive storytelling systems. Barber and Kudenko [23] present an interactive story generator system that learns the personality of its users by applying predefined increments or decrements to a vector of personality traits, such as honesty and selfishness, in response to the users' decisions. Seif El-Nasr [24] presents an interactive storytelling system called Mirage, where both player behavior and personality are modeled in order to allow users to participate in a more engaging drama. The system tracks user's actions to adjust a vector of values representing tendencies toward character traits (heroism, violence, self-interestedness, and cowardice). Sharma et al. [25] present an interactive storytelling system that combines past captured game traces and player survey data to create player models, which are used to dynamically determine the next plot point that is best suited to specific users. Thue et al. [26] present PaSSAGE, an interactive storytelling system that uses player modeling to automatically learn a model of the player's preferences through observations of the player in the virtual world, and then uses the model to dynamically select the content of an interactive