Personalised Gaming

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Abstract

This article focuses on personalised games, which we define as games that utilise player models for the purpose of tailoring the game experience to the individual player. The main contribution of the article is a motivation for personalised gaming, supported by an extensive overview of scientific literature. The motivation concerns (a) the psychological foundation, (b) the effect on player satisfaction, (c) the contribution to game development, and (d) the requirement for achieving ambitions. The provided overview of scientific literature goes into the subject of player modelling, as well as eight adaptive components: (1) space adaptation, (2) mission / task adaptation, (3) character adaptation, (4) game mechanics adaptation, (5) narrative adaptation, (6) music / sound adaptation, (7) player matching (multiplayer), and (8) difficulty scaling. In the concluding sections, the relationship to procedural content generation is discussed, as well as the generalisation to other domains.

Introduction

Recently, it can be observed that there is a shift in focus towards the design of video games for individuals, so as to increase perceived value (Chiou & Wong, 2008). Indeed, a benefit of such player-centred design is that it ideally results in enhanced gameplay experiences for players regardless of gender, age or experience (Charles & Black, 2004; Charles et al., 2005; Medler, 2009; Sykes & Federoff, 2006). Though it is indicated that player-centred game design approaches can be applied to all stages of the game development process (Sykes & Federoff, 2006), a comparison study shows that in practice its application is limited to (1) market research and pre-production play testing, (2) pre-release usability and play testing, (3) post-release maintenance, (4) empowering players with control, and (5) in-game player support systems (Stewart, 2007). It results in games focused on a limited demographic, wherein by design the individual player is not considered specifically.

It is argued that we are now at a unique point where modern computer technology, simulation, and artificial intelligence (AI) have opened up the possibility that more can be done with regard to on-demand and just-in-time personalisation (Riedl, 2010). With computational techniques available that model a player's behaviour, experience, and satisfaction, games that are truly personalised are within reach. Here, we define a personalised game as follows:

> *A personalised game is a game that utilises player models for the purpose of tailoring the game experience to the individual player.*

At this point, we need to make a precise distinction between 'personalised' and the related term 'adaptive'. Indeed, tailoring the game experience to a player is implemented by adapting part of the game (e.g., the artificial intelligence of game characters). When game adaptations are not informed by the actual player in one way or the other, we refer to the game as being strictly adaptive. When, on the other hand, the adaptations are informed by the player, e.g. by determining automatically the difficulty level appropriate to the current player, we refer to the game as being personalised (albeit, in a modest way). In this regard, a game that is strictly personalised is a game in which every single component of the game is tailored to the individual player; a goal that may be practically unachievable to even the most ambitious of game designers.

In this article, we provide a motivation for personalised gaming, and provide an extensive overview of scientific literature with regard to required components (player modelling) and optional components (space adaptation, mission/task adaptation, character adaptation, game mechanics adaptation, narrative adaptation, music/sound adaptation, player matching (multiplayer), and difficulty scaling). The scope of the article concerns video games, where insight on generalisation to other domains is provided in the discussion section.

The outline of the article is as follows. We first discuss the motivation for incorporating personalisation techniques in the domain of video games (Section 2). Subsequently, we go further into a required component of personalised games: player modelling (Section 3). Next, we discuss optional components of a personalised game, together with the advances being made herein (Section 4). Then, we discuss the relationship to procedural content generation (PCG) and go into the subject of generalisation and synthesis of personalisation techniques (Section 5). Finally, a conclusion is provided (Section 6).

Why personalisation?

Research and development of personalised games has numerous motivations, of which we highlight the psychological foundation (2.1), the effect on player satisfaction (2.2), the contribution to game development (2.3), and the requirement for achieving ambitions (2.4). We hereby attempt to provide a holistic perspective on the motivations of existing personalisation work.

2.1 Psychological foundation

Studies on persuasion reveal a significantly increased involvement and extensive cognitive elaboration when subjects are exposed to content of personal relevance (Petty & Cacioppo, 1979; Petty, Cacioppo & Schumann, 1983). Concomitant with the greater attention, studies show that more highly involved individuals (i.e., subjects in the high personal relevance condition) will exhibit stronger emotional reactions when they are in a high elaborative frame of mind (Darley & Lim, 1992). A seminal work on emotion theory by Izard (2009) hypothesizes that emotion will have substantial and measurable effects on cognition and action when the stimulus or situation is a personally or socially significant one.

This matches the so-called appraisal theory (Lazarus, 1991), according to which a necessary and sufficient condition for emotion is that the person's current life situation is appraised as impinging significantly on personal concerns. In layman terms, an event has to matter to the person experiencing it to cause emotion (Parkinson, 1996).

Now, an important question is: what makes events personally important in this way? Part of the answer to this question is that events often achieve their personal significance in the course of ongoing social encounters and the development of relationships between people (Parkinson, 1996). Another part of the answer is that particular emotional significance is also defined by broader cultural value systems (e.g., (Lutz, 1988; Rosaldo, 1984)). An observation herein, relevant to game design, is that emotions depend on events that impact on the progress of personal projects (e.g., Carver & Scheier, 1990; Frijda, 1986; Mandler, 1984); pursuits common to all members of the species (e.g., food, shelter, sex) as well as culturally supplied aims such as wealth, reputation, freedom and self-esteem. Adequately modelling the target demographic, but foremost the individual player herein, provides additional tools for designing personally significant game experiences.

Psychological studies showed that a proper fit between personality and environment can raise productivity and/or satisfaction (Kristof, 1996). These findings imply that when applied to a game environment, player satisfaction will benefit from a correct fit between personality and environment (Schreurs, 2011). Similar arguments can be made with regard to maintaining player immersion (Manovich, 2002; Taylor, 2002) and flow (Cowley, Charles, Black & Hickey, 2008), though we consider such detailed discussions outside the scope of the present article.

2.2 Effect on player satisfaction

Players are now expecting a more personalised gaming experience as personalisation has begun to filter into most games (Zad, Angelides & Agius, 2012). Research has suggested that game personalisation raises player loyalty and enjoyment, which in turn makes gaming experience a (commercial) success (Teng, 2010 Turkay & Adinolf, 2010). This supports the overarching thesis that an appropriate fit between characteristics of the player and gaming technology results in greater enjoyment (Fang & Zhao, 2010).

In recent years it has been possible in many video games for players to design and personalise their own in-game characters. In a study by Fischer, Kastenmuller and Greitemeyer (2010), it was predicted that this innovation could lead to elevations in the intensity of the psychological effects of video games. Process analyses by Fischer, Kastenmuller & Greitemeyer (2010) revealed that participants playing a violent video game with a personalised game character experienced more arousal and self-activation than they did when playing with an impersonal, default game character, which in turn increased aggressive responses. A follow-up study by Hollingdale and Greitemeyer (2012) confirmed these findings.

One may reasonably assume that the results generalise to other video-game genres, particularly as it has already been shown that acting prosocially increases empathy and decreases *schadenfreude* in prosocial games (Greitemeyer, Agthe, Turner & Gschwendtner, 2012; Greitemeyer & Osswald, 2010; Greitemeyer, Osswald & Brauer, 2010), and that video racing games increase risk-taking inclination (Fischer et al., 2009). Personalisation of game characters may indeed accentuate the indicated effects.

2.3 Contribution to game development

The perspective of AI researchers to increase the engagement and enjoyment of the player is one that is consistent with the perspective of game designers (Riedl, 2010). That is, where usability and user modelling for other software may be based on productivity alone, games require an additional factor that accounts for the quality of the user experience in playing a game (Cowley, Charles, Black & Hickey, 2006).

Riedl (2010) correctly states that scaling of tailored experiences requires intelligent systems that “can take progressively more responsibility for the player’s experience by automating tasks such as design of level, NPC behaviors and dialogue, plot and quests, and game mechanics themselves”. These tasks have historically been the domain of human creative designers, actors, dungeon masters, and so on. The decisions that need to be made about the player’s experience, however, can only be made in a just-in-time and on-demand fashion. That is, the system needs to know (a) who the user is, (b) what the user needs, preferences, and desires are, and (c) what the user is doing at any given moment (Riedl, 2010). Achieving scalable personalisation requires work towards practical human-level computational creativity; a goal aspired by both researchers and game developers.

Much in the same way as procedural content generation is used in the game *Left 4 Dead* to increase the output of the development team and promote replayability

(Booth, 2009), it can be implied that personalised procedural content can enhance replayability even further.

2.4 Requirement for achieving ambitions

Though the personalisation of games generally yields ambitious connotations, an important use of personalisation in game design has already become commonplace: to provide explicit advice to the player. This was done as early as 1985 in *Patton Versus Rommel* and again in 1987 with*Trust & Betrayal*; both games being designed by Chris Crawford.

Experts have indicated that advances in game design and AI would fundamentally change the way games are designed (Laird & van Lent, 2001; Stern, 1999), and allow the creation of entirely new types of games (Molyneux, 2006). On this subject, the ambition was expressed that “advances will also allow players to have entirely unique experiences as each time you play a given scenario it will evolve differently, and will allow far richer, more realistic worlds to be created as more and more elements react more believably” (Molyneux, 2006). Though this may be an over-enthusiastic image with regard to the current state of the industry, increasingly more research is invested in the automatic generation and personalisation of game environments, which may lead to fulfilling at least some of said ambitions.

Player Modelling

A personal experience in games requires the gaming system to accurately assess the individual player; it requires player modelling. Player modelling concerns establishing models of the player, and typically, exploiting the models for personalised play. A player model is an abstracted description of a player or of a player’s behaviour in a game. The general goal of player modelling is to steer the game towards a predictably high player satisfaction (van den Herik, Donkers & Spronck, 2005), based on the player model.

Here we highlight player behavioural modelling, which is of increasing importance in modern video games (Furnkranz, 2007). The main reason is that player behavioural modelling is almost a necessity when the purpose of AI is ‘entertaining the human player’ rather than ‘defeating the human player’ (van den Herik, Donkers & Spronck, 2005). A challenge for such player modelling in video games is that models of the player have to be established (1) in game environments that generally are realistic and relatively complex, (2) with typically little time for observation, and (3) often with only partial observability of the environment. The online creation of player models, or the classification of the player into previously established models, is a task that has to be performed real-time, while other computations, such as rendering the game graphics, are performed simultaneously. Researchers estimate that generally only twenty per cent of all computing resources are available to the game AI (Millington, 2006). Of this twenty per cent, a large portion will be spent on rudimentary AI behaviour, such as manoeuvring game characters within the game environment. This implies that only computationally inexpensive approaches to player modelling are suitable for incorporation in the game AI.

For the domain of modern video games, four approaches are deemed applicable to player behavioural modelling, namely (1) modelling actions, (2) modelling tactics, (3) modelling strategies, and (4) profiling a player (Bakkes, Spronck & van Lankveld, 2012). In this taxonomy, action models concern game actions that can be observed directly or that can be inferred from other observations. Tactical models concern short-term/local game behaviour as composed of a series of game actions. Strategic models concern long-term/global game behaviour as composed of a series of game tactics, of which the behaviour may span the entire game, several game iterations, and across distinct games. Player profiling acknowledges that employing certain game actions, tactics, and strategies is motivated by the (psychological) profile of the player; distinct motivations and affect may result in distinct strategies, tactics, and actions. An illustration of the adopted taxonomy of player behavioural modelling is given in Figure 1. Indeed, the defined classes are not mutually exclusive; one can for instance capture player tactics and a player profile in a single model.[1] An interesting superset of player behavioural modelling, is called player experience modelling – and is generally focussed on modelling a player's fun, frustration, and challenge.[2]

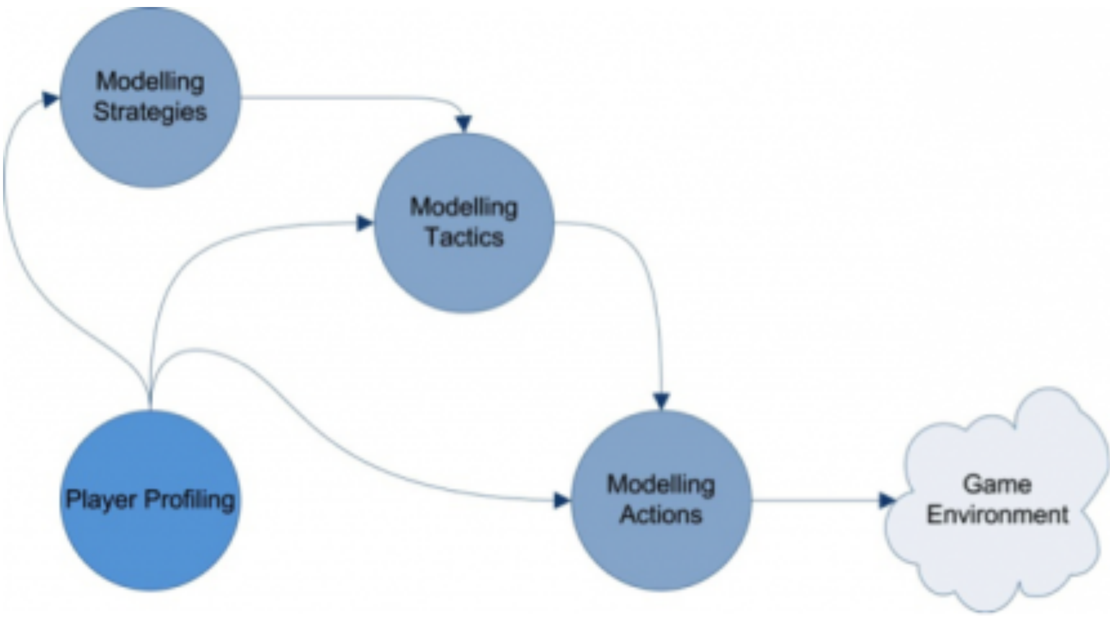

Figure 1. Taxonomy of player behavioural modelling by means of indirect measurements of the human player (i.e., utilising actual in-game observations to generate player models) (Bakkes, Spronck and van den Herik, 2009).

Action models. If we examine the defined classes of models respectively, we notice that they are increasingly resource-intensive to construct; however, they also

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[1] The following descriptions are derived from Bakkes, Spronck & van Lankveld (2012), to which we refer the reader for references to additionally interesting literature, such as Charles & Black, 2004; Charles et al, 2005; Houlette, 2004; Sharma, Mehta, Ontanon & Ram, 2007; Smith, Lewis, Hullet, Smith & Sullivan, 2011.

[2] For further reading on modelling player experience, we refer the reader to (Pedersen, Togelius & Yannakakis, 2009; Yannakakis, 2008; Yannakakis, Maragoudakis & Hallam, 2009; Yannakakis & Togelius, 2011). Also, interesting related work concerns a taxonomy of player motivations in video games (Bartle, 2996; Yee, 2006).

increasingly generalise better. When considering the predictive capabilities of these types of models, action models attempt to do what most game developers would like player models to do, namely predict player actions. If exact future actions are known, determining a good response is relatively easy. While action prediction seems an attractive possibility of a model, in practice it is of limited use, unless the games concerned are relatively uncomplicated. The predictions of the other model types become increasingly less specific, but also more generally applicable for direct use (i.e., without requiring additional learning trials); a characteristic relevant for generalising over observations.

Tactical and strategic models have a lot of potential, especially when the goal of a game is to provide a strong challenge for the human player. Inherently, tactical and strategic models are capable of more generalisation than is possible on solely an action-state level. Hence, tactical and strategic models provide a better means for game developers to personalise and adapt the game experience and challenge to the level of individual players.

Player profiling is of a different calibre, though comprised of predominantly ongoing research. By incorporating psychologically-verified knowledge in player models (e.g., the Five Factor Model of personality (FFM), cf. Digman, 1990; McCrae & Costa Jr, 1997), as well as knowledge on player experience and satisfaction, player profiling may potentially have a substantial (and more directly noticeable) impact on the experience that users have with a gaming system. We note that numerous cross-domain applications exist for player modelling approaches, such as in interactive storytelling or, in gaming environments that are generated online, on the basis of a player's behaviour and experience.

Components of a Personalised Game

To tailor the game experience to the individual player requires player models (discussed in Section 3), as well as components that use these models to adapt part of the game. Though by no means an exhaustive list, we present a set of components that will allow the vast majority of video games to be personalised.

The components, of which at least one needs to be implemented in a personalised game, are space adaptation (4.1), mission/task adaptation (4.2), character adaptation (4.3), game mechanics adaptation (4.4), narrative adaptation (4.5), music/sound adaptation (4.6), and player matching (multiplayer) (4.7). Where desired by the game designer, the components may be informed by difficulty-scaling techniques for adjusting the challenge level to the individual player (4.8). An illustration of the proposed taxonomy is given in Figure 2.

4.1 Space adaptation

A natural starting point for adaptation, and exploiting player models, is to allow the space in which the game is played to evolve in response to the actual behaviour of the player (Dormans & Bakkes, 2011). Generally, and firstly, after observing the player for a select period of time, features within the established player model may indicate that it is recommendable to transform (gradually) the game surroundings. For instance, transform from open to confined spaces, from linear to more organic environments, and from easily manoeuvrable corridors to intricate mazes. Secondly, variations in gameplay may be provided by, in addition, allowing events that take place within certain game spaces (e.g., particular rooms) to respond to the player's previous behaviour. For instance, if the player models indicate that a specific player consciously avoids narrow, dark passageways, the space adaptation process may purposely generate more such passageways (e.g., in the case of a horror game), or, inversely, adapt the existing space to be less confining.

Straightforward implementations of space-adaptation techniques have been incorporated in video games such as Rogue, Diablo, Torchlight, Spore, and MineCraft. Space adaptation, generally in the context of procedurally generated games, is an active area of research (Pedersen, Togelius & Yannakakis, 2009; Smith, Treanor, Whitehead & Mateas, 2009; Dormans, 2010; Douglas & Hargadon, 2001).

4.2 Mission/task adaptation

A promising alternative to space adaptation, is to allow the game's mission to evolve in response to observed behaviour of the player. A strategy in this regard, is to generate a mission that still has some open ends in its structure before constructing the space (Dormans & Bakkes, 2011). The subsequent replacement of these open ends occurs during play, and, ideally, is directly or indirectly informed by the performance of the player. For instance, obtaining a certain in-game achievement by the player may trigger a dynamically generated parallel mission to be inserted at an open end.

In turn, the space in which the mission takes place may grow in response to the changes in the mission, or may already have accommodated all resulting possibilities. This could quite literally lead to an implementation of an interactive structure that Marie-Laure Ryan calls a fractal story; where a story keeps offering more and more detail as the player turns his attention to certain parts of the story (Ryan, 2009).

Adapting the game's mission in response to behaviour of the player is relatively challenging, as the game's mission needs to be tightly controlled by the game designer. As such, mission adaptation is generally overlooked by game designers, or implemented only in a modest form. For instance, game designers may opt for pre-selecting available missions dependent on the game character's (often pre-defined) background and goals (such as in the game World of Warcraft), or have player decisions effect later missions in the same game (such as in the game The Witcher) (Vanhatupa, 2011; Tychsen, Tosca & Broland, 2006). On the other hand, incorporation of the actual gameplay experience in a dynamic adaptation process is regarded as an important yet relatively recent direction of research (Cousins, 2004; Adams & Rollings, 2006; Dormans, 2010; Dormans & Bakkes, 2011).

4.3 Character adaptation

The task for game AI is often focused on controlling game characters in such a way that behaviour exhibited by the characters is consistent within the game environment. In a realistic game environment, realistic character behaviour is expected. As a result, game AI that is solely focused on exhibiting the most effective behaviour is not necessarily regarded as realistic. For instance, in a typical first-person shooter (FPS) game it is not realistic if characters controlled by game AI aim with an accuracy of one hundred per cent. Game AI for shooter games, in practice, is designed to make intentional mistakes, such as warning the player of an opponent character's whereabouts by intentionally missing the first shot (Liden, 2004). Consistency of computer-controlled characters within a game environment is often established with tricks and cheats. For instance, in the game Half-Life, tricks were used to establish the illusion of collaborative teamwork (Laursen & Nielsen, 2005), causing human players to assume intelligence where none existed (Liden, 2004). While it is true that tricks and cheats may be required to uphold consistency of the game environment, they often are implemented only to compensate for the lack of sophistication in game AI (Buro & Furtak, 2004). In practice, game AI in most complex games still is not consistent within the game environment, and exhibits what has been called 'artificial stupidity' (Liden, 2004) rather than artificial intelligence.

The ability of game characters to adapt to changing circumstances has been explored with some success in previous research (Demasi & de O Cruz, 2002; Graepel & Herbrich, 2006; Spronck, Sprinkhuizen-Kuyper & Postma, 2004). This ability is called 'adaptive game AI'. When implemented successfully, adaptive game AI is able to fix errors in programmed game AI, and to seek counter-tactics to human gameplay. Research done by Spronck (2005) indicated that machine learning techniques may be used to establish adaptive AI in complex video games. There are two different approaches in which machine learning may be applied to establish adaptive game AI, namely (1) offline learning, and (2) online learning. In addition, there are two different approaches in which a machine-learning technique for game AI can be controlled, namely (1) human-controlled learning, and (2) computer-controlled learning.[3]

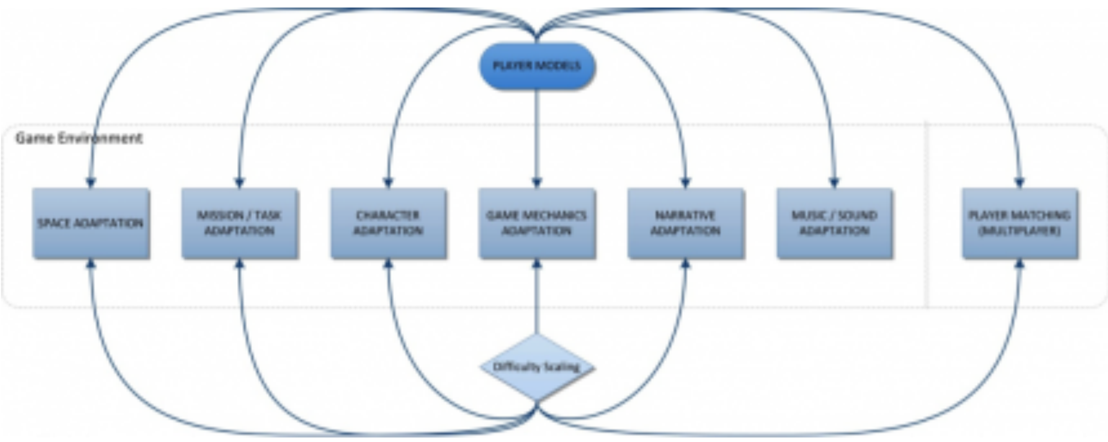

Figure 2. Personalised gaming, as resulting from player models (required) that steer at least one of the optional components (1) space adaptation, (2) mission / task adaptation, (3) character adaptation, (4) game mechanics adaptation, (5) narrative adaptation, (6) music / sound adaptation, and (7) player matching (multiplayer), while being informed by (8) difficulty-scaling techniques where desired.

[3] For a detailed description of these approaches, the reader is referred to Bakkes (2010).

Generally, one can observe that learning effective behaviour while the game is in progress (i.e., 'online'), typically requires an inefficiently large number of learning trials. In addition, it is not uncommon that a game has finished before any effective behaviour could be established, or that game characters in a game do not live sufficiently long to benefit from learning. As a result, it is difficult for players to perceive that the game AI is learning. This renders the benefits of online learning in video games subjective and unclear (Rabin, 2008). In addition, even with advanced approaches to game AI (e.g., Aha, Molyneux & Ponsen, 2005; Auslander, Lee-Urban, Hogg & munoz-Avila, 2008; Baumgarten, Colton & Morris, 2009; Sharma et al, 2007), it is often difficult to establish effective behaviour in a controlled and predictable manner. Therefore, a body of research has focused specifically on how to create rapidly and reliably effective behaviour of game AI (Bakkes, Spronck & van den Herik, 2009; Bakkes, 2010).

Although most research focuses on adapting the behaviour of game characters, character adaptation may also entail altering the appearance and locomotion of characters.

4.4 Game mechanics adaptation

Though video games exist that purposely vary their game mechanics during actual gameplay, e.g., the critically acclaimed game Braid, video games that adapt their mechanics based on the player are rare. In the game Max Payne 3, a mechanism unknown to players alters the level of mechanics such as aim assistance, according to individual skills (thus adjusting shooting difficulty) (Lopes & Bidarra, 2011); a game-mechanics based application of difficulty scaling.

Research exists, however, on the automated identification of gameplay schemas and schema-based adaptation of game mechanics (Lindley & Sennersten, 2006), with the goal of generating emergent game-play (Salen & Zimmerman, 2004). Leading contributors to this line of work are Nelson and Mateas (2007), who have researched automated game design for many years. Also, emergent game design is a topic being investigated by Dormans (2012).

4.5 Narrative adaptation

Adapting a game's narrative has long been the forefront of research into interactive storytelling. Interactive storytelling can be defined as "a gaming experience where the form and content of the game is customized in real time and tailored to the preferences and needs of the player to maximize enjoyment" (Bostan & Matsh, 2010). After all, the fundamental goal of interactivity is stated to present the user with different choices to be able to receive a highly personalised end result (Sundar, 2007). The challenge herein, is to support meaningful player choices without the loss of plot coherence or narrative quality (Tanenbaum, 2011; Paul et al., 2009). To this end, the field of interactive storytelling covers a wide range of technologies and models.[4]

In the context of personalisation, we observe that the domain of interactive storytelling has seen numerous advances in terms of chaining together appropriate actor actions, directing scenes toward a dramatic goal (e.g., the work of Mateas and Stern (2005) on *Façade*), or planning to achieve a learning objective (El-Nasr, 2007; Crawford, 2004; Riedl & Stern, 2006).

The utilisation of player models for interactive fiction is regarded an important subject, and has been investigated by Sharma, Mehta, Ontanon and Ram (2007). Particularly, player-modelling techniques may enrich systems by incorporating psychologically-verified knowledge on player satisfaction and experience (Bakkes, Spronck & van Lankveld, 2012). A promising system in this regard, is PaSSAGE, an interactive storytelling system which bases its storytelling decisions on an automatically-learned model of each player's style of play (Thue, Bulitko, Spetch & Wasylishen, 2007; Thue, Bulitko & Spetch, 2008). In addition, a good example of personalised interactive storytelling is SSAU, a system which focuses specifically on inferring an affective preference from the player's interactions, and modulates the visual and auditory presentation of the storyworld in response (Tanenbaum & Tomizu, 2007; Tanenbaum & Tomizu, 2008).

4.6 Music/sound adaptation

The distinguishing feature of game music is that it responds to the player to some extent (Belinkie, 1999); a form of adaptation that has been common practice since early video games (Schmidt, 1989). As a somewhat recent example, a game, which utilises interactive music, is*Banjo Kazooie*. As you walk around, the instrumentation and scoring of the main theme gradually changes. As you approach a beach, the music becomes a reggae arrangement. As you approach a snowy mountain, a chiming Christmassy set of instruments fades in. An aquatic area features a rollicking pirate sound. The melody never changes, but the style of it is constantly adjusting to the terrain (Belinkie, 1999).

Studies state that by simultaneously enriching the worlds of video games and assisting the player's navigating the space of video games, music is essential to the semantic operations of video games (Whalen, 2004), and is regarded as a prominent contributor to the processes of immersion, engagement and flow in the reception of hypertext and digital narratives (Douglas & Hargadon, 2001). In this regard, expressions of emotion are crucial for increasing believability; a fundamental aspect of music is its ability to express emotions (Eladhari, Nieuwdorp & Fridenfalk, 2006). Two interesting functions of music herein, are to induce mood, and to heighten the sense of absorption (cf. Cohen, 1999). Regarding the first function, indeed, it has been shown that music can induce mood to a listener (Pignatiello, Camp & Rasar, 1986). Regarding the second function, in previous work, Gabrielsson and Lindstrom

[4] We refer the reader to Riedl, Thue & Bulitko (2011) for an overview of literature on the general subject of interactive narrative.

(2001) show how different factors in musical structure affect the perceived emotional expression.

Though still in relative infancy, key research into the personalisation of game music and sound is being performed. That is, Nacke, Grimshaw and Lindley (2010) have successfully studied the measurement of sonic user experience and psychophysiology. Also, Livingstone and Brown (2005) implemented a prototypical gaming environment wherein the music tracks adjust in real-time to the emotion of the in-game state.

4.7 Player matching (multiplayer)

Research has shown that when opponent players play too poorly in a game against a particular player, the player loses interest in the game (Scott, 2002). In addition, research has shown that when opponent players play too strongly in a game against a particular player, the player will get frustrated (i.e., 'gets stuck' in the game) and will quit playing too (Livingstone & Charles, 2004; van Lankveld, Spronck & van den Herik, 2009). In this regard, it is important for a gaming system to rate the skills of players accurately, and to match players with comparable skills with one-another; close enough in skill to be challenging, but not so difficult as to be frustrating (Graepel & Herbrich, 2006). Rating the skills can be based on heuristics put forward by the game developer, or by objective measures such as an ELO rating (Elo, 1978); a number which expresses the relative skill of a player, as determined by winning/loosing matches against other players. Now, a challenge for determining a player's skill level in numerous video games, is that (1) game outcomes often refer to team of player, while skill rating for individual players is needed for future matchmaking, and (2) more than two players or teams compete such that the game outcome is a permutation of teams or players rather than just a winner and a loser (Herbrich, Minka & Graepel, 2007). To address these challenges, Microsoft Research developed the *TrueSkill* rating system, which is an extension of Mark Glickmam's rating system Glicko (Glickman, 1995).

4.8 Difficulty scaling

Techniques can be applied for automatically adapting the challenge that a game poses to the skills of a human player. This is called difficulty scaling (Spronck, Sprinkhuizen-Kuyper & Postma, 2004), or alternatively, challenge balancing (Olesen, Yannakakis & Hallam, 2008). When applied to game dynamics, difficulty scaling aims usually at achieving a 'balanced game', i.e., a game wherein the human player is neither challenged too little, nor challenged too much. In most games, the only implemented means of difficulty scaling is typically provided by a difficulty setting; a discrete parameter that determines how difficult the game will be. The purpose of a difficulty setting is to allow both novice and experienced players to enjoy the appropriate challenge that the game offers. Usually the parameter affects plain in-game properties of the game opponents, such as their physical strength. Only in exceptional cases the parameter influences the strategy of the opponents. Consequently, even on a 'hard' difficulty setting, opponents may exhibit inferior behaviour, despite, for instance, their high physical strength. Because the challenge provided by a game is typically multifaceted, it is difficult for the player to estimate reliably the particular difficulty level that is appropriate for himself. Furthermore, generally only a limited set of discrete difficulty settings is available (e.g., easy, normal, and hard). This entails that the available difficulty settings are not fine-tuned to be appropriate for each player.

In recent years, researchers have developed advanced techniques for the difficulty scaling of games. Demasi and Cruz (2002) used coevolutionary algorithms to train game characters that best fit the challenge level of a human player. Hunicke and Chapman (2004) explored difficulty scaling by controlling the game environment (i.e., controlling the number of weapons and power-ups available to a player). Spronck, Sprinkhuizen-Kuyper and Postma (2004) investigated three methods to adapt the difficulty of a game by automatically adjusting weights assigned to possible game strategies. In related work, Yannakakis and Hallam (2007) provided a qualitative and quantitative method for measuring player entertainment in real time. Knowledge on the effect of certain game adaptations can be utilised to maintain a certain challenge level (cf. Bakkes, Spronck & van den Herik, 2009; Bakkes, Spronck & van den Herik, 2009), and may be incorporated to steer the procedural generation of game content (cf. Dormans & Bakkes, 2011).

Finally, techniques for game pacing are gradually being implemented in actual video games. For instance, the game *Left 4 Dead* automatically adjusts the game pacing to maximise player excitement/game intensity (Booth, 2009). The technique is implemented by estimating and tracking the 'emotional intensity' of the players. If the intensity is deemed too high, major threats are remove temporarily, otherwise, interesting threats are created on-the-fly. Another example is the game *Uncharted 3*, which in certain scenarios subtly decreases the speed of the game if players die repeatedly in the concerning scenario (Krekel, 2012).

Discussion

We conclude the overview of literature with a discussion on the relationship of personalised gaming to procedural content generation (5.1), insight on personalisation in other gaming domains (5.2), and synthesis of personalisation techniques (5.3).

5.1 The relationship to procedural content generation

In the domain of video games, procedurally generated content is considered to be of increasing importance to the computer-game development in the present and in the future; both offline, for making the game development process more efficient (design of content such as environments and animations now consume a major part of the development budget for most commercial games), and online, for enabling new types of games based on player-adapted content (Pedersen, Togelius & Yannakakis, 2009; Dormans & Bakkes, 2011).

Here we should be explicit about the relationship of personalised gaming to procedural content generation (PCG). Personalised gaming is about tailoring the game content to the individual player (which does not necessarily require game content to be generated automatically). PCG is about the automatic generation of game content (which does not necessarily entail the content is tailored to the individual player). Personalised gaming requires content to be tailored to the individual player, while the method for doing so is open. Take, as a minimal example, a mobile picture puzzle that is personalised using real-world camera input (Mahamad, Mazlan, Kasbon, Khalid & Rusdi, 2007). As another example, educational games may provide a personalised learning experience based on adequately estimating the player's skills (Peirce, Conlan & Wade, 2008). It is true, however, that for many types of games and for numerous tasks, procedural content generation may indeed be the preferred method for tailoring content to the player. For instance, the feasibility of procedurally generating a personalised race track has been demonstrated by Togelius et al. (2007).[5]

5.2 Generalisation to other domains

In this article, we focused on personalisation in video games. Indeed, to a large extent personalisation techniques can generalise to other gaming domains. First, a clear contribution lies in the domain of educational games (and by extension, other serious games), where personalised learning has already indicated its benefits (Peirce & Wade, 2010; Peirce, Conlan & Wade, 2008; Gobel, Wendel, Ritter & Steinmetz, 2010). Second, *ambient games* have been shown to benefit from player behavioural analysis for adapting the game context (Dansley, Stevens & Eglin, 2009; Schouten, Tieben, Ven & Schouten, 2011). Third, in classic games such as chess, it has been shown that accurately modelling the opponent player can increase the playing strength (Donkers, Uiterwijk & van den Herik, 2001; Donkers, Uiterwijk & van den Herik, 2003), but moreover can be applied for scaling the playing strength to be appropriate to the human player (van den Herik, Donkers & Spronck, 2005) for entertainment purposes.

Analogous to the concepts in Yannakakis & Togelius (2011), player modelling and adaptation techniques required for personalised gaming are regarded as applicable to other human-computer interaction (HCI) domains, such as recommender systems, web 2.0 applications, interface design and computational creativity and art. Here, the user driving the generation process, and the designer deciding at a high-level which type of adaptations to make available, provides an innovative mixture of both user-driven and design-driven content creation (Yanakakis & Togelius, 2011).

5.3 Synthesis of personalisation techniques

Having discussed numerous and distinct techniques for personalised gaming, it is clear that the main challenge for personalised gaming lies in the combination of personalisation techniques, and in its incorporation into a game's design.

One may argue that it would be useful to characterise personalisation in terms of the scope of data that enters into the personalisation computations. For instance, a personalisation calculation with a scope of single in-game actions – that is, something that merely reacts to individual moves – should be intrinsic to the game

[5] For further reading, an article by Yannakakis and Togelius (2011) provides an overview of experience-driven procedural content generation. Also, research by Lopes and Bidarra (2011) provides an in-depth study on adaptivity challenges in games and simulations, foremost in the context of adaptivity and procedural content generation.

and should not be considered personalisation. Proper personalisation would require the analysis of aspects of large numbers of in-game actions. The personalisation algorithm used would have to examine some parameter emerging from a statistical analysis of the data comprised by the player's moves. This implies that by relying solely on observations of present gameplay, personalisation cannot take place early in the game – an observation that would, we believe, be useful to point out. However, it is possible to use large-scale data collected from online games to assess the play of an individual player. By data mining the mass of data on play behaviour and consequent success, it is possible to establish reliable evaluations of individual play. This idea was investigated by Bakkes, Spronck & Herik (2009a), who generated automatically a case-base of a multitude of gameplay experience, with which they were able to classify accurately the human player even early in the game, and derive automatically an evaluation function that rates the player's behaviour (Bakkes, Spronck & Herik, 2009b).

Approaches for personalised gaming may be expected to be most successful when implemented in a framework that strictly considers designing for player immersion. One such framework is proposed by Lopes & Bidarra (2011); it is aimed at creating personalised content for complex and immersive game worlds, and captures which content provided the context for a given personal gameplay experience. This model is then used to generate content for the next predicted experience, through retrieval and recombination of semantic gameplay descriptions, i.e. case-based mappings between content and player experience (Lopes & Bidarra, 2011). Through its integration with existing player and experience modeling techniques, these frameworks aim at generating, in an emergent way, game worlds that better suit players.

Conclusions

In this article we focused on personalised games, which we defined as games that utilise player models for the purpose of tailoring the game experience to the individual player. The main contribution of the article is a motivation for personalised gaming, supported by an extensive overview of scientific literature. Indeed, research and development of personalised games has numerous motivations, of which we highlighted the psychological foundation, the effect on player satisfaction, the contribution to game development, and the requirement for achieving ambitions.

In a proposed taxonomy of personalised gaming, player modelling techniques are a requirement for steering adaptive components that a game may have. Acknowledging that by no means an exhaustive list of such components can be established, the article investigated literature with regard to (1) space adaptation, (2) mission/task adaptation, (3) character adaptation, (4) game mechanics adaptation, (5) narrative adaptation, (6) music/sound adaptation, (7) player matching (multiplayer), and (8) difficulty scaling. In a concluding discussion of the article, the relationship to procedural content generation (PCG) was discussed, as well as the generalisation to other domains.

For future work, the main challenge is in the combination of personalisation techniques, and in its incorporation into a game's design. Indeed, with personalisation directly and positively influencing the game experience, game design is expected to develop into an increasingly less predetermined direction.

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