Dynamic Game Balancing by Recognizing Affect

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Abstract. Dynamic game balancing concerns changing parameters in a game to avoid undesired player emotions, such as boredom and frustration. This is e.g. done by adjusting the game's difficulty level to the (increasing) skill level of the player during the game. Currently, most balancing techniques are based on in-game performance, such as the player's position in a race. This is, however, insufficient since different types of players exist, with different goals, preferences and emotional responses. Therefore, to deal effectively with a player's emotions, a game needs to look beyond the player's performance. This paper provides an overview of two groups of potentially useful sources for dynamic game balancing: Overt behavior and physiological responses. In addition, we present EMO-Pacman, a design case that aims to implement these new balancing techniques into the game Pac-Man.

Keywords: Computer games, emotionally adaptive games, game balancing, affective loop, psychophysiology, emotions.

1 Introduction

To be enjoyable, a computer game must be balanced well. Adams & Rollins [1] list a number of requirements for a well-balanced game. For instance, a game must provide meaningful choices, the role of chance should not be so great that player skills become irrelevant, and players must perceive the game to be fair. Concerning the fairness of a (player-versus-environment) game, it is of key-importance that the game's difficulty is adjusted to the player's abilities. This is what many believe to be at the core of game balancing: Changing parameters in order to avoid undesired player emotions such as frustration (because the game is too hard) or boredom (because the game is too easy) [2]. Since the player's abilities tend to increase throughout the game, the game's difficulty level should be adapted continuously. Hence the need for dynamic game balancing.

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Currently, a number of heuristic techniques are used for dynamic game balancing, which try to assess the game's perceived difficulty level given a particular game state. Examples of these heuristics are I) the rate of successful shots or hits, II) number of life points, III) time left to complete a task and IV) the player's current position in a race. Regarding the latter heuristic, a commonly applied adaptation technique is rubber banding [3]: When falling behind, the player suddenly gets a boost in speed, which allows for catching up again (and/or the competing cars are slowed down).

However, game adaptation that is solely based on in-game performance can only have limited success, because there are many different types of players [4]. Each type of player has his/her own goals, preferences and emotional responses when playing a game. Therefore, taking the emotional (or affective) state of the player into account is expected to increase interest and fun; games can become *emotionally adaptive*. Results and approaches from research disciplines such as psychophysiology and affective computing can help in realizing this.

2 Emotionally Adaptive Games

Three types of methods for measuring affect can be distinguished [5]: Through self-reporting, by analyzing overt behavior and by analyzing physiological responses. For game balancing in a real-time environment, self-reporting is too obtrusive. However, self-reporting can be used to validate the results of the other two types. Regarding overt behavior[1], a number of potentially interesting techniques have previously been studied in an affective computing context. Techniques and studies focused on overt behavior that seem particularly useful for dynamic game balancing are provided in Table 1. A more detailed overview can be found at [6]. The relations between affect and physiological responses are investigated in the field of psychophysiology. A number of relevant techniques and studies can be found in Table 1; more detailed overviews can be found in e.g. [7] and [8].

Table 1. Potential sources for real-time analysis of affect

Overt behavior / expressions
Posture analysis, force exerted on game controls, facial emotions, gestures analysis, speech analysis.
Physiological responses
Heart rate (HR), Heart rate variability (HRV), Respiration rate (RSPRATE), Coherence between respiration rate and heart rate (RSP-HR_COH), Blood pressure, Blood volume pulse (BVP), Activity of the corrugator supercilii muscle, (CORR: for moving the eye-brows), Activity of the zygomaticus major muscle, (ZYG: for moving the cheeks), Activity of the orbicularis oculi muscle (OO: for moving the eye-lids), Skin conductance level (SCL), Skin conductance responses (SCR), Eye movements (EOG), Pupil size, Eye blink rate, Brain activity at various frequencies (EEG), Evoked Response Potential (ERP).

[1] In this category, we also include behavioral phenomena that are less overt, such as keyboard force (which is measured through sensors).

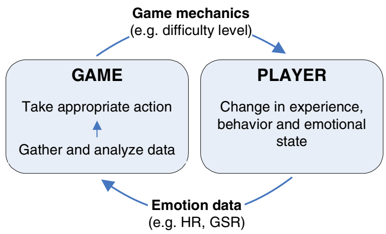

Fig. 1. The emotionally adaptive games loop, inspired on [9] and [16]

From an emotion-perspective, effective human-computer interaction can be realized using an "affective loop" [9]. Fig. 1 shows an affective loop that is tailored to the games domain. By providing the right game mechanics (e.g. audiovisuals, narrative, challenge), the game influences the player's experience, behavior and emotional state. During play, the emotional state of the player (measured in terms of *emotion-data*, such as the types mentioned in Table 1), is continuously being fed back to the game so that the game can adapt its mechanics (e.g. difficulty level) accordingly in real-time. All of this is done with the aim to optimize the experience.

Previous research attempts to create emotionally adaptive software have mainly focused on tutoring systems / productivity software (see e.g. [10]). Fewer attempts have been made to incorporate a closed-loop mechanism in a games context. Several authors [11, 12] have created games that improve player performance by adapting the difficulty level to the player's physiological state. Concept validation claims of these two studies were, however, based on a limited number of subjects. Besides these attempts, a number of biofeedback games have recently been developed, integrating the player's physiological data into the game (e.g. [13,14]). These games focus on stress manipulation rather than optimization of gameplay experience. Closest to the concept described in Fig. 1 probably is the work by Saari and colleagues. They created the Mind-Based Technology framework for psychological customization [15] and, based on this, initiated a framework for emotionally adaptive games (e.g. [16]).

To obtain empirical support for the emotionally adaptive games concept, an emotionally adaptive version of the game Pac-Man is currently being developed in the EMO-Pacman project, as described in the next section of this paper.

3 EMO-Pacman

EMO-Pacman (explained in more detail in [17]) is a two-stage attempt to create a game (adapted from Pac-Man, [18]) that adjusts its speed to the player's current emotional state. In the first stage of the project, we investigated the relations between the individual elements of the emotionally adaptive games framework (Fig. 1). The main research question in this stage was "What game mechanic setting causes what kind of emotional state, and what emotion-data is this accompanied by?"

To investigate this, a user test was conducted involving 24 adult subjects. One game mechanic, *game speed*, was manipulated, consisting of 3 levels (referred to as slow-mode, fast-mode and normal-mode). Changes in speed affected both the player's character (Pac-Man) and his/her opponents (ghosts). Speed was selected as an

Table 2. Effects of game speed on emotion-data

Significant ($p < 0.05$) results	
Feature	**Speed mode identified (desired action)**
Mean SCL	slow (speed up)
Number of SCR	slow (speed up)
Mean HR	slow (speed up)
Mean RSPRATE	slow (speed up)
Mean ampl. of the CORR signal	fast (slow down)
Mean ampl. of the ZYG signal	fast (slow down)
Mean key-press force	slow (speed up) & fast (slow down) & normal (none)
No significant results	
Mean value of the CORR signal, mean value of the ZYG signal, mean value of the BVP signal, mean ampl. of BVP signal, mean RSP-HR_COH, HRV: mean power perc. of the 0.04-0.15Hz spectrum.	

independent variable since it is relatively simple to manipulate, and speed changes were expected to have a strong influence on the player's emotional state. Different from the original Pac-Man version, the objective was not to stay alive and finish all levels. Instead, the objective was to score as many points. The player gained points by letting Pacman eat objects (scared ghosts, points, fruit) and lost points when Pacman was eaten by one of his opponents (angry ghosts). During the test, the game was paused twice to let the player report on their emotional state (bored / frustrated / enjoyed). In parallel, a series of emotion-data features was recorded during game play (see Table 2), explained in more detail in [17].

From the results, it seems that the "too easy - boredom" and "too hard - frustration" combinations do not always apply, because 2 participants reported frustration in the slow-mode and 2 others reported boredom in the fast-mode. Nevertheless, a strong majority (83%) reported boredom in the slow-mode. Although the fast-mode was considered enjoyable by some (58%) and frustrating by others (33%), almost all participants (96%) indicated in the post-game interview to prefer the normal mode over the slow- and fast-mode. Therefore, we conclude that I) the slow-mode was considered boring, II) the fast-mode was enjoyable for some but frustrating for others and III) the normal-mode was the most enjoyable mode. A series of t-tests was performed to investigate the influence of the factor game speed on the emotion-data, as shown in Table 2.

From the preliminary results of this experiment, displayed in Table 2, we can e.g. conclude that the players' mean skin conductance level (SCL) during the slow-mode was significantly different from that during the other two speed-modes (i.e. slow and fast).

4 Discussion and Further Work

As argued for, we believe that games can strongly benefit from analyzing the user's affective state when playing a game. The research fields of e.g. affective computing and psycho(physio)logy offer several potentially useful techniques for continuous analysis of a player's emotional state. The first experiment in the EMO-Pacman project has provided some preliminary empirical evidence for this. The project's ultimate goal is to create an emotionally adaptive game demonstrator. The results from Table 2 can be useful in creating such a classifier. For instance, when a player's skin conductance level drops low during Emo-Pacman, this may indicate boredom because I) the strong majority of subjects in the first experiment found the slow-mode boring, and II) on average (over 24 subjects) the SCL values were significantly lower during this speed mode than during the other two modes. Even though differences in physiological responses between individuals and within individuals over time are not uncommon (see e.g. [19]), the results from Table 2 can be used as a starting point.

One of the main challenges ahead is to create a properly functioning decision making system. For instance, how to respond when two emotion data features indicate boredom but two others do not? In this context, AI-based techniques (e.g. [20]) are expected to be more powerful than only performing statistical tests. Therefore, as a first step in the next phase, a classifier will be tested with the present dataset. In case the results of this test will prove unsatisfactory (e.g. insufficient data/accuracy), unused additional features from the gathered dataset will be analyzed. For instance, the subjects' faces were recorded with a webcam during the experiment (providing possibilities for facial emotion tracking). In addition, other possibilities lie e.g. in analyzing the initial/previous physiological states [21][2] of the players, analyzing the amplitude / recovery time of their skin conductance responses and looking at the variance, skewness and kurtosis of the emotion-data ([22] and [23] provide more detailed feature analysis descriptions).

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References

1. Adams, E., Rollings, A.: Game Design and Development; Fundamentals of Game Design. Pearson Education, NJ (2007)
2. Koster, R.: Theory of Fun for Game Design. Paraglyph Press, Phoenix (2004)
3. Pagulayan, R.J., Keeker, K., Wixon, D., Romero, R., Fuller, T.: User-centered design in games. In: Jacko, J., Sears, A. (eds.) Handbook for Human–Computer Interaction in Interactive Systems, pp. 883–906. Lawrence Erlbaum Associates Inc, Mahwah (2002)
4. Bartle, R.A.: Hearts, Clubs, Diamonds, Shades: Players who suit MUDs, `http://www.mud.co.uk/richard/hcds.htm`
5. Öhman, A.: The Psychophysiology of Emotion: An Evolutionary-Cognitive Perspective. In: Ackles, P.K., Jennings, J.R., Coles, M.G.H. (eds.) Advances in Psychophysiology, vol. 2, pp. 79–127. JAI Press, Greenwich (1987)

[2] For example, a high (140 BPM) heart rate might not increase as much by an arousing game effect as a normal heart rate.

6. The HUMAINE portal; Research on Emotions and Human-Machine Interaction, http://emotion-research.net
7. Ravaja, N.: Contributions of Psychophysiology to Media Research: Review and Recommendations. Media Psychology 6, 193–235 (2004)
8. Allanson, J., Fairclough, S.H.: A research agenda for physiological computing. Interacting with Computers 16(5), 857–878 (2004)
9. Sundström, P., Ståhl, A., Höök, K.: eMoto - A User-Centred Approach to Affective Interaction. In: Tao, J., Tan, T., Picard, R.W. (eds.) ACII 2005. LNCS, vol. 3784. Springer, Heidelberg (2005)
10. Schaefer, F., Haarmann, B.W.: The Usability of Cardiovascular and Electrodermal Measures for Adaptive Automation. In: Westerink, J.H.D.M., Ouwerkerk, M., Overbeek, T.J.M., Pasveer, W.F., De Ruyter, B. (eds.) Probing Experience: From Assessment of User Emotions and Behavior to Development of Products. Philips Research Book Series, vol. 8, pp. 235–243 (2008)
11. Takahashi, M., Tsuyoshi, A., Kuba, O., Yoshikawa, H.: Experimental Study Toward Mutual Adaptive Interface. In: Proceedings of the 3rd IEEE International Conference on Robot and Human Communication, Nagoya, Japan, pp. 271–276 (1994)
12. Rani, P., Sarkar, N., Liu, C.: Maintaining Optimal Challenge in Computer Games Through Real-Time Physiological Feedback. In: Proceedings of the 1st International Conference on Augmented Cognition, Las Vegas, NV (2005)
13. Journey to Wild Divine, http://www.wilddivine.com
14. Bersak, D., McDarby, G., Augenblick, N., McDarby, P., McDonnell, D., McDonald, B., Karkun, R.: Intelligent Biofeedback Using an Immersive Competitive Environment. In: Abowd, G.D., Brumitt, B., Shafer, S. (eds.) UbiComp 2001. LNCS, vol. 2201. Springer. Heidelberg (2001)
15. Saari, T.: Mind-Based Media and Communications Technologies. How the Form of Information Influences Felt Meaning. Acta Universitatis Tamperensis 834. Tampere University Press, Tampere (2001)
16. Saari, T., Ravaja, N., Turpeinen, M., Kallinen, K.: Emotional Regulation System for Emotionally Adapted Games. In: Proceedings of FuturePlay 2005, Michigan State University, MI (2005)
17. Tijs, T.J.W., Brokken, D., IJsselsteijn, W.A.: Creating an Emotionally Adaptive Game (submitted)
18. Overmars, M., McQuown, B.: Pac-Man. GM6 [computer software]
19. Lacey, J.I., Lacey, B.C.: Verification and extension of the principle of autonomic response stereotypy. Am. J. Psychol. 71, 50–73 (1958)
20. Yannakakis, G.N., Hallam, J.: Towards Optimizing Entertainment in Computer Games. Applied Artificial Intelligence 21, 933–971 (2007)
21. Berntson, G.G., Cacioppo, J.T., Quigley, K.S.: Autonomic Determinism: The Modes of Autonomic Control, the Doctrine of Autonomic Space, and the Laws of Autonomic Constraint. Psychological Review 98(4), 459–487 (1991)
22. Picard, R., Vyzas, E., Healey, J.: Toward Machine Emotional Intelligence: Analysis of Affective Physiological State. IEEE Transactions on Pattern Analysis and Machine Intelligence 23(10), 1175–1191 (2001)
23. Van den Broek, E.L., Schut, M.H., Westerink, J.H.D.M., Van Herk, J., Tuinenbreijer, K.: ECCV 2006 Workshop on HCI. In: Huang, T.S., Sebe, N., Lew, M., Pavlović, V., Kölsch, M., Galata, A., Kisačanin, B. (eds.) ECCV 2006 Workshop on HCI. LNCS, vol. 3979, pp. 52–63. Springer, Heidelberg (2006)