AudioNode : Prototypical Affective Modelling in Experience-driven Procedural Music Generation

Elise Plans, Davide Morelli, David Plans
Royal Holloway University of London, University of Pisa, University of Surrey
Elise.Plans.2014@live.rhul.ac.uk, morelli@di.unipi.it, d.plans@surrey.ac.uk

Abstract

This paper presents current work under development that furthers previous research from the authors in Experience-Driven Procedural Music Generation for games. Recent work is explored in context in affective modelling and biosignal-driven evaluation. A framework for establishing affective states and their bi-directional influence into gameplay elements is presented.

Introduction

Procedural content generation (PCG) offers great advantages towards creating music that adapts more granularly to player experience, avoiding repetition and providing an evolving, more emotionally intelligent soundtrack. Procedural music can be defined as composition that evolves in real time according to a specific set of rules or control logics (Collins 2009, p. 3). PCG has an established body of work (Togelius et al. 2011). Some of this work attempts to personalize gameplay via affective and cognitive modeling, adjusting content in real-time according to the user's needs and preferences, driven by computational models of user experience (Yannakakis and Togelius 2011), in what is known as Experience-Driven Procedural Content Generation (EDPCG). In our previous work (Plans and Morelli 2012) we looked at how EDPCG might be applied to music composition for gameplay, using the MarioAI Championship engine, hinting at then recent developments in audio engines such as libpd, an embeddable version of Pure Data, a music programming framework that has been used by in empirical studies that investigate whether PCG music could can elicit target affective states in a listener (Scirea et al. 2014). [1]. Here, we introduce libpd-based approaches to Experience-Driven Procedural Music Generation (EDPMG).

Implementation

To continue our previous work, we chose to fork NodeReviver, a simple maze game developed by Vincent Petry for MiniLD 33 [2]. The player's job is to reconnect nodes that have lost their connections to each other, moving from node to node using the arrow keys. The player can only move when standing on a node, so an element of forward thinking and planning is involved to avoid enemy drones. The game was written in Python using the Pygame engine, and we used libpd as a wrapper to interface between the game and music. We named our fork of NodeReviver AudioNode, to follow in the tradition of Audioverdrive (Holtar, Nelson, and Togelius 2013) and AudioInSpace (Hoover et al. 2015), both experimental games that use PCG audio/music. Audioverdrive was developed to have bidirectional communication between enemies, visual elements of gameplay, and gameplay itself, requiring hard coding by developers between musical elements and mapped visual/gameplay features. In AudioInSpace, audio, visuals and gameplay were integrated to procedurally generate weapon appearance, gameplay effects, and soundtrack. The soundtrack then in turn influenced weapon appearance, creating bidirectional communication.

Affect Modelling

Our eventual objective is to test AudioNode using techniques outlined in previous work in affective adaptive interaction in games (Yannakakis, Martínez, and Jhala 2010), in which computational models of discrete affective states of fun, challenge, boredom, frustration, excitement, anxiety and relaxation were built on biosignals (heart rate, blood volume pulse and skin conductance). The aim for our test will be to ascertain whether EDPMG can significantly reduce anxiety and frustration, and increase parasympathetic (whilst reducing sympathetic) arousal.

These three biosignals were chosen by Yannakakis et al because they are correlated to sympathetic arousal (Rosalind W. Picard, Elias Vyzas, Jennifer Healey), and more recent efforts towards subject-dependent automatic stress detection also use these biosignals (Giakoumis, Tzovaras, and Hassapis 2013). Having begun work with Microsoft Research using their flagship wearable (the Band) for corporate stress management mobile applications, we see positive results in continuous HR and Heart Rate Variability (HRV) data harvesting, which will allow us to create a test-bed for AudioNode in a mobile app with live HRV and electrical skin conductance from the Band.

As the current prototype does not yet have automatic biosignal capture, we decided to firstly implement simple mappings of three basic affective states during game-

[1] https://github.com/libpd/libpd

[2] https://github.com/PVince81/nodereviver

play; the current variables describe the affective state of the avatar/gameplay, rather than the player. The introduction of biosignal capture in the next stage of our work will embrace the human player in the affective modelling loop. Our mappings are as follows:

Frustration This metric is calculated as the ratio between deaths vs total number of played games. Frustration is normalized between 0 and 1. When the player is winning most of the games, frustration is close to zero. When the player is losing all the games, frustration is close to one. Frustration only changes when a game is won or lost.

Planning calculated as the ratio between the number of new nodes the player reaches vs the total number of nodes visited in the current level. This metric attempts to capture how effectively the player is planning the moves. If the player is not capable of reaching new nodes, because of the presence of the enemies, planning will be near zero, indicating that the player is not actively solving the level. If the player does not return often to the same nodes, exploring new nodes while avoiding enemies, planning will be near to 1, indicating that the player is in control of the game. This metric is updated every time the player makes a move.

Danger calculated as the reciprocal of the average distance from enemies, where distance is defined as the number of nodes that separate an enemy from the player, as show in equation 1, where Δ_i is the distance in nodes between the i^{th} enemy and the player. If all enemies are only one node away, the player needs to move quickly to avoid being killed, fear is 1. If all the enemies are far from the user, danger quickly drops towards 0. Danger is normalized between 0 and 1, and changes every time any of the enemies or the user change position.

$$danger = \frac{1}{\frac{1}{n}\sum_i^n \Delta_i} \tag{1}$$

Audio Mappings

The chosen game parameters are mapped in the following ways: Danger is mapped to tempo with an inverse ratio so that the greater the danger, the slower the tempo. Danger is also mapped to the frequencies of the diegetic pitches, which sound when a node is activated. Finally, at the highest danger level, the kick and snare are removed from the music. These choices are made with the intention to create a calmer soundscape with minimal distractions when the player is facing greater difficulty. Planning is used to trigger a filter above a certain threshold, so that players who plan well, are rewarded with rich timbral variations in the tonal components of the music. Frustration is mapped to note length, with a view to creating noticeable, quirky, staccato rhythms to divert attention from irritating gameplay.

Progress through the level is mapped to reverb, gradually rewarding the player with a richer sound as the level nears completion following the example of Bit Trip Runner (Aksys Games, 2010). A tentative exploration of using second-order Markov chains to generate the bassline, by weighting note-choices, in an attempt to create continuously varying music that still has musical coherence, has been implemented at a basic level, with potential to be developed further. Current state of development for AudioNode can be seen here: http://bit.ly/audionode

Next Stage of Development

We will next contextualise our work within recent procedural game soundtrack generation that looks at Russell‘s circumplex model of affect to parametrise emotional responses to musical stimuli across valence and arousal (Williams et al. 2015) and then undergo a perceptual affective evaluation following the outlined biosignal model.

References

Collins, K. 2009. An introduction to procedural music in video games. *Contemporary Music Review* 28(1):5–15.

Giakoumis, D.; Tzovaras, D.; and Hassapis, G. 2013. Subject-dependent biosignal features for increased accuracy in psychological stress detection. *Int. J. Hum. Comput. Stud.* 71(4):425–439.

Holtar, N. I.; Nelson, M. J.; and Togelius, J. 2013. Audioverdrive: Exploring bidirectional communication between music and gameplay. In *Proceedings of the 2013 International Computer Music Conference*. kmjn.org.

Hoover, A. K.; Cachia, W.; Liapis, A.; and Yannakakis, G. N. 2015. AudioInSpace: Exploring the creative fusion of generative audio, visuals and gameplay. In *Evolutionary and Biologically Inspired Music, Sound, Art and Design*, Lecture Notes in Computer Science. Springer International Publishing. 101–112.

Plans, D., and Morelli, D. 2012. Experience-Driven procedural music generation for games. *IEEE Trans. Comput. Intell. AI Games* 4(3):192–198.

Rosalind W. Picard, Elias Vyzas, Jennifer Healey. Toward machine emotional intelligence: Analysis of affective physiological state. In *IEEE Transactions on Pattern Analysis and Machine Intelligence*.

Scirea, M.; Nelson, M.; Cheong, Y.-G.; and Bae, B. C. 2014. Mood expression in real-time computer generated music using pure data.

Togelius, J.; Yannakakis, G. N.; Stanley, K. O.; and Browne, C. 2011. Search-Based procedural content generation: A taxonomy and survey. *IEEE Trans. Comput. Intell. AI Games* 3(3):172–186.

Williams, D.; Kirke, A.; Eaton, J.; Miranda, E.; Daly, I.; Hallowell, J.; Roesch, E.; Hwang, F.; and Nasuto, S. J. 2015. Dynamic game soundtrack generation in response to a continuously varying emotional trajectory. In *Audio Engineering Society Conference: 56th International Conference: Audio for Games*. Audio Engineering Society.

Yannakakis, G. N., and Togelius, J. 2011. Experience-Driven procedural content generation. *Affective Computing, IEEE Transactions on* 2(3):147–161.

Yannakakis, G. N.; Martínez, H. P.; and Jhala, A. 2010. Towards affective camera control in games. *User Model. User-adapt Interact.* 20(4):313–340.