A Computational Model of Suspense for Non-Narrative Gameplay

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***Abstract*—In recent years, Various mechanisms have been proposed to optimize for players' emotional experience. In this paper, we focus on suspense, one of the key emotions in gameplay. Most previous research on suspense management in games focused on narratives. Instead, we propose a new computational model of Suspense for Non-Narrative Gameplay (SNNG). SNNG is built around a Player Suspense Model (PSM) with three key factors: hope, fear, and uncertainty. These three factors are modeled as three sensors that can be triggered by particular game objects (e.g., NPCs) and game mechanics (e.g., health). A player's feeling of suspense can be adjusted by altering the level of hope, fear, and uncertainty. Therefore, an SNNG-enhanced game engine could manage a player's level of suspense by adding or removing game objects, diverting NPCs, adjusting game mechanics, and giving or withholding information. We tested our model by integrating SNNG into a Pacman game. Our preliminary experiment with nine subjects was encouraging.**

***Index Terms*—Games, Affective computing, Human computer interaction**

I. Introduction

Previous studies have shown that the feeling of suspense is one of the major factors that contribute to the enjoyment of games [1]–[3]. Researchers have proposed various mechanisms to generate and manage suspense in games [4]–[10]. However, most previous works deal with story-driven games and focus on generating suspense by generating or managing narrative content. In this project, we want to explore the possibility of generating and managing suspense in games without using narrative content. We want to study whether it is possible to manage suspense through low-level game mechanics, independent of the narrative layer.

In this paper, we propose a new computational model for generating and managing suspense in games – Suspense for Non-Narrative Gameplay (SNNG). SNNG centered around a player Suspense Model (PSM). Our PSM is based on the standard cognitive model of suspense [11] that identifies hope, fear, and uncertainty as the key factors that generate suspense. In our PSM, these three factors are modeled as three sensors. Particular game objects (e.g., enemy NPCs) and game mechanics (e.g., health and timer) can trigger one or more of the three sensors to generate hope, fear, uncertainty. Information detected from these game objects, or game mechanics can alter the amount of hope, fear, or uncertainty a player feels at the moment. Therefore, a game engine can estimate the amount of suspense a player feels based on the combination of hope, fear, and uncertainty. The game engine can also adjust the level of suspense a player feels by adding, deleting, or manipulating particular game objects and game mechanics. For example, the game engine can slow down or divert certain enemy NPCs to reduce fear. The game engine can also give or withhold information about enemy NPCs or the goal of the game to adjust the level of uncertainty.

To test our model, we have implemented two versions of Pacman: a regular Pacman game (non-affective version) and a Pacman game with SNNG (affective version). A desirable suspense arc is embedded in the affective version. We conducted a preliminary experiment with nine subjects. Four subjects played the non-affective version, and five subjects played the affective version but without prior knowledge. We measured their heart rates and also asked them to rate their anxiety level at different points of the game while reviewing their gameplay recordings. Our results show that the group played the affective version showed higher levels of anxiety throughout their playthrough. However, the self-rated anxiety levels were not always consistent with the desired suspense curve. The preliminary results of our study are encouraging, but the sample size is too small to draw reliable conclusions. This is still a work in progress and we plan to conduct more experiments to collect more data.

II. Related Work

Several cognitive models of suspense have been proposed [11]–[15]. Among them, the cognitive model proposed by Ortony, et al. [11], also known as the OCC model, is the most widely accepted. In this model, suspense is generated by three factors: hope, fear, and uncertainty. These cognitive models have been applied to game studies [3], [8], [9]. Moulard, et al. [3] proposed a conceptual model of suspense for games, largely based on the hope, fear, and uncertainty factors. Sayol and Colum Pons [9] argued that uncertainty is less important for generating suspension in video games because of the loop structure in games. Instead, the knowledge a player gains about the obstacles from a previous play will enhance the

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expectations (hope and fear) for the current play and therefore elevate suspense. Smut and Frome [8] argued that helplessness is a major factor for generating suspense and, in video games, suspense can be managed by giving or removing options for a player.

Turning theoretical models of emotions into computational models has long been a challenge. A number of researchers have proposed computational models of suspense and tension [4]–[7], [10], [16]. Giannatos, et al. [7] proposed a computational model that uses a planner to generate solutions to the planning problem imposed by a set of predefined and procedurally generated plan operators. A fitness function will evaluate the solutions based on the model proposed by Gerrig and Bernardo [12]. In this theory, readers' reports of suspense are moderated by their perceptions of the range of solutions available to a textual dilemma. Cheong and Young [6] also proposed a plan-based model of narrative comprehension to determine the final content of the story in order to manipulate the reader's suspense. Also, based on Gerrig and Bernardo's theory [12], O'Neill and Riedl's computational model [5] generates plans for the protagonist to avoid an impending negative outcome and measures the suspense level by determining its perceived likelihood of success. In Szilas and Richle's model [16], tension is generated by creating paradoxical narratives. Doust and Piwek's model of suspense for narrative generation [10] is based on Brewer and Lichtenstein's theory [15]. In this model, the suspense of each narrative thread is measured by four parameters: imminence, importance, foregroundedness, and confidence.

Previous models focus on generating, selecting, and organizing narrative events based on certain suspense fitness functions. Our proposed model of suspense is different from the previous computational models of suspense in two ways. First, our model does not use narrative events to generate suspense. Instead, our model uses the interactions between players and game objects to generate suspense. Second, our computational model of suspense is based on the OCC model [11], which is generally considered the standard for emotional modeling in affective computing. Most other computational models of suspense are not based on the OCC model. While most of the previous models of suspense are for narrative-driven games, our model can be applied to non-narrative games.

III. A Computational Model of Suspense for Non-Narrative Gameplay

Our proposed Computational Model of Suspense for Non-Narrative Gameplay (SNNG) consists of two main components: a Player Suspense Model (PSM) and a Game Object Suspense Model (GOSM). The player Suspense Model (PSM) specifies a suspense-aware avatar. Suspense-Aware avatars can receive information from the game world to change the avatar's level of suspense. The level of suspense for each avatar can be quantified based on the OCC suspense model [11]. In this model, suspense is generated by a combination of three factors: hope, fear, and uncertainty. In this paper, for simplicity, we focus on single-player games and assume there is only one avatar.

The Game Object Suspense Model (GOSM) gives particular game objects the ability to manipulate an avatar's level of suspense through hope, fear, and uncertainty. Therefore, the interactions between a suspense-aware avatar and suspense-aware game objects during gameplay can continuously alter the level of suspense for the avatar. A game engine can use SNNG to manage the level of the suspense for the avatar based on a pre-defined emotional arc.

A. Player Suspense Model

In the Player Suspense Model, the suspense-aware avatar has three elementary emotional states: hope, fear, and uncertainty. The intensity of each state is represented by a numerical value that can be manipulated by particular game objects (e.g., NPCs). For example, the detection of an enemy NPC can increase fear. Not knowing the location of an enemy NPC can increase uncertainty. Knowing the location and distance of the goal can increase hope.

The level of suspense felt by the avatar is the weighted sum of the hope, fear, and uncertainty value. Game designers may adjust the weights for hope, fear, and uncertainty.

$$\begin{aligned} suspense_{total} = c_0 hope_{total} \\ + c_1 fear_{total} \\ + c_2 uncertainty_{total} \end{aligned}$$

where c0, c1, and c2 are different weights associated with each component and hope, fear, and uncertainty are the sum of all the indices for each game object tracked.

We understand that the calculated level of suspense for the avatar is not necessarily the same suspense felt by the human player. However, since a human player experiences a game through his or her avatar, and because OCC's suspense model is widely accepted as a reasonable cognitive model of suspense, our hypothesis is that the suspense felt by the human player will be close to the simulated suspense for the avatar, thus making the emotional experience of gameplay more predictable and (hopefully) more enjoyable.

B. Game Object Suspense Model

The Game Object Suspense Model specifies how certain game objects can manipulate the level of suspense for the suspense-aware avatar (SAA) by feeding the suspense-aware avatar a set of hope, fear, and uncertainty values. The specific details may vary from game objects to game objects and will be determined by game designers and developers. Here are some typical examples.

A game designer can add the following properties to an NPC (or game object).

- Is the avatar aware of the existence of this game object?
- Does the avatar know the location of this game object?
- Can the avatar see this game object?
- Can the avatar hear this game object?

- The distance between this game object and avatar
- Is this game object hostile or friendly to the avatar?
- The speed of this game object
- The damage this game object can apply to the avatar
- The amount of help this game object can give to the avatar

A game programmer can write a script to specify how to feed different hope, fear, and uncertainty values to the suspense-aware avatar (SAA) based on the values of the properties. For example, if the avatar is aware of the existence of this game object but does not know its location, then feed a positive value of uncertainty to the avatar. If the avatar can hear this avatar but cannot see it, then feed a lower value of uncertainty to the avatar. If the avatar can see this game object, then feed an even lower value of uncertainty to the avatar.

If this game object is hostile to the avatar, then send a positive value of fear to the avatar. If this game object is getting closer to the avatar, then feed an even higher value of fear to the avatar. If this game object is helpful to the avatar (e.g., a health kit), then send a negative fear value to the avatar to reduce fear.

If this game object is a shelter and is visible to the SAA, then send a positive value of hope to the avatar. If the avatar is getting closer to this game object, send a higher value of hope to the avatar.

GUI objects can also be used to manipulate the avatar's level of suspense. For example, as a timer is counting down, the timer can feed higher and higher values of fear to the avatar. Each time a life is lost, the "life" object can feed a higher value of fear to the avatar.

At each game update cycle, the suspense-aware avatar will receive a set of hope, fear, and uncertainty values from each suspense-aware game object. The values from each game object may be weighted based on its significance (e.g., how much damage this game object can apply to the SAA). These values will be added to generate accumulated values of hope, fear, and uncertainty, which are used to calculate the combined suspense value for the suspense-aware avatar.

This gameplay-based suspense engineering mechanism to steer a player towards a desirable emotional arc [17]. If the avatar's current suspense value is too far from the target suspense value on the emotional arc, the program can use the available suspense-aware game objects to reduce or increase the avatar's level of suspense. For example, the program can slow down a hostile NPC or provide additional weapons to reduce fear. Or give the avatar more information about the goal or NPC to reduce uncertainty.

IV. Implementation and Preliminary Experiment

To test our model, we built a 3D version of the classic game, Pacman (Figure 1) using Unity. The reason for building a 3D version is because it is simpler to use our model in a first-person view where a human player sees and hears what the avatar sees and hears. Two versions were built: the affective version included the computational suspense model and the regular version did not. In both versions, the player has a minimap that displays their location in the maze as well as the location of the pacdots. The position of the ghosts and power pellets are hidden from the player, but the player can see the ghosts in the corridors and can hear the ghosts within a certain radius. The GUI includes a score bar, timer, and the number of ghosts and power pellets left.

In the affective version, uncertainty is defined as the number of unknowns in the game; hope is defined as how close the player is to accomplishing their goal; fear is defined as how close the player is to lose. Ghosts, pacdots, power pellets, scores, and timer are used as suspense-aware game objects.

For the affective version, we also created a target emotional arc for each level based on the research described in [17], The game will adjusted the behavior of the game object based on the difference between the estimated suspense curve and the target suspense curve.

We recruited nine volunteers for our study. All the subjects were undergraduate students participating in a summer research program. Five participants played the Affective version, and four played the Non-Affective version. For each participant, we measured the participant's resting heart rate and their heart rate throughout the game. We also asked each participant to watch his or her gameplay video and rate their anxiety level at different checkpoints.

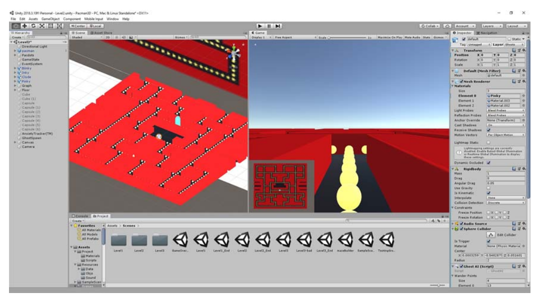

Fig. 1. A screenshot of the 3D Pacman game used in our experiment

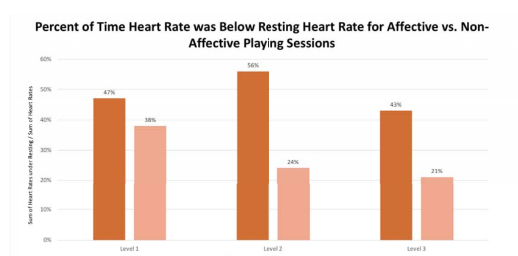

Fig. 2. This graph displays the average percentage of time players' heart rates were at or below resting heart rate while playing the game.

V. Results and Discussion

We used heart rate as a measure of the level of anxiety or suspense the player experienced during the playthrough and gathered user anxiety ratings at certain points on the anxiety curve. Research in [18] shows that heart rate lowers when a person experiences anxiety. Thus, Figure 2 shows the

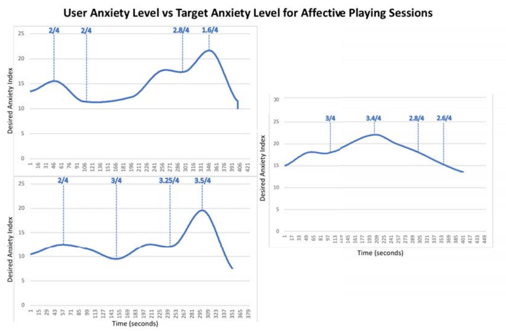

Fig. 3. This graph displays average user anxiety level ratings verses target suspension curve for key points on the graph.

percentage of time players' heart rates were lower than resting heart rate for each level. In level 1, participants who played the Affective version had lower heart rates 47% of the time versus 38% for players of the Non-Affective version. In level 2, participants who played the Affective version had lower heart rates 56% of the time versus 24% for players of the Non-Affective version. In level 3, participants who played the Affective version had lower heart rates 43% of the time versus 21% for players of the Non-Affective version.

Figure 3 shows the average user anxiety ratings versus the desired suspense curves for different levels. The numbers on the chart are the average user rating of their anxiety at different points of the game. These ratings were obtained by asking each subject to rate his or her anxiety levels while watching the gameplay videos. The average ratings are only from participants who played the affective version of the game. Level 1 demonstrated the least fit between relative ratings and position on the curve due to the climax point on the curve corresponding to the lowest anxiety rating. Level 3 showed the best fit because the first point is lower than the highest point, and the subsequent points linearly decrease in intensity. Since the sample size is small, more experiments need to be done for more reliable analysis.

These preliminary results demonstrate the promise of our computational model of suspense. Participants who played the Affective version of the game consistently showed lower heart rates and thus higher levels of anxiety throughout their playthrough, suggesting that these players were more often on the "edge of their seat" compared to players of the Non-Affective version. Additionally, with tweaking, the anxiety curves could be accurate estimations of anxiety. During the experiment, we observed that players did not pay attention to the status bar in the upper left corner of the screen, which displays how many ghosts are present in the maze. One factor we use to calculate fear is by assigning a small threat index to each ghost present in the maze, but if players do not attend to these details, they could not feel threatened by the ghosts in the maze if they are not directly in the player's line of sight or range of hearing. This could result in players reporting lower levels of anxiety than we anticipated at particular moments.

VI. Conclusion and Future Work

We have discussed a computational model of suspense for non-narrative gameplay. Using this model, we can generate and manage user suspense using only gameplay, without narrative events. This model can be used for non-narrative-driven games or to supplement narrative-based computational models of suspense in story-driven games. The results from our preliminary experiment are encouraging. But our sample size is small, and we plan to conduct more experiments to test our model.

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