CSCE 681 600: SEMINAR REPORT 5

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1. SUMMARY:

a. Problem Statement:

The authors in this paper have presented an adaptive biofeedback game that changes the difficulty of the gameplay with respect to the physiological state of the player which is recorded by wearable sensors, in order to maintain the arousal of the player. In their method, the interplay between the difficulty of the game and the physiology of an individual during gameplay is modeled as a control problem, with the arousal of the player serving as the output of the system and the difficulty of the game serving as the input of the system. The authors in this work have proposed a method of arousal management using the alluring world of gaming. They have presented a generic mechanism of adapting a game with the aim of keeping the player's arousal at a constant level.
The authors have proven the effectiveness of their strategy using a car-racing game with mechanics that can be adjusted in real-time. The authors have used control theory where they are treating the player as a dynamic system and they are trying to change his varying arousal levels into a constant level of arousal by manipulating the difficulty level of the game with respect to the recorded electrodermal activity. They have manipulated 3 game mechanics, used 2 types of control laws, and treated electrodermal activity as a measure of arousal of the individuals in their experiments. According to the authors, physiological sensors will help in developing new types of gameplay and solutions beyond amusement, such as increasing engagement and involvement, adjusting the difficulty of the game to the skill level of the player, and designing treatment strategies that take advantage of the appeal of games.

b. Proposed solution:

In their control system design, the authors are treating (1) the player as the "plant" whose arousal level they want to keep constant around a certain fixed point (2) the electrodermal activity of the player which is measured by physiological sensors as a measure of the arousal level of the player that is used in the feedback loop to the system (3) the difference between the recorded arousal level of the player and pre-determined desired arousal level as the deviation signal to the game adaptation engine which manipulates the parameters of the game to reduce this deviation. The authors have used an adaptive car-racing game that provides feedback that is unimodal in nature and have used the steering, speed, and visibility mechanics of the game for the purpose of adapting the game. The physiological feedback was obtained from an EDA sensor and the player had to only control the steering of the car in the modified game. An average speed profile for the car at different parts of the circuit was pre-determined using 10 different recorded gameplays of a skilled player.

The authors had manipulated the 3 different game adaptation types to manipulate the difficulty of the game as follows: (1) The authors changed the weather conditions between rain, fog, and snow to change the weather modality for the purpose of affecting the visibility of the road by the player (2) The authors used additive noise at every 0.5s interval to create disturbances which were random in nature to the direction of steering of the player to lessen his sense of control in the steering modality (3) The authors manipulated the speed of the car in a linear fashion between 40 to 80 mph using a multiplicative factor applied to the previously determined average speed on different parts of the racing track to change the speed modality. The difficulty of the game based on these 3 modalities was varied from 0% to 100%. To measure the arousal of the player, electrodermal activity (EDA) was utilized as it is known to have a linear relationship with arousal. EDA has 2 basic components, (1) SCL (skin conductance level) and (2) SCR (skin conductance responses). Since SCL is dependent on the subject and the site of the electrode and it can be hard to measure while an SCR is observed, therefore only the SCR is used for the purpose of EDA measurement.

25 students with minimal gaming experience had participated in the experimental trials conducted by the authors. 20 of them had evaluated the Proportional control (P-control) adaptation for manipulating the steering, weather, and speed, and 5 of them had evaluated the Proportional, Integral, Derivative control (PID-control) adaptation for manipulating the speed of the game. The experiments consisted of 3 phases In Phase 0 the participants played the game for 1 lap with no feedback to get accustomed to the game and its control settings. In Phase 1, (also called the open-loop phase which ran for 8 minutes in total) the participants played the game where one of the 3 game mechanics was varied at a certain step sequence to change the difficulty level between 0, 50, and 100% at every step with each step lasting for 1 minute. In this phase, the participants' EDA data at different difficulty levels were recorded with no biofeedback enabled to get the target setpoint for the next closed loop phase using the average of this data. In Phase 2, (also called the closed loop phase) was divided into 2 five-minute sessions with a two-minute break in between. In this phase, the difficulty of the game was adjusted to maintain the EDA of the player at the setpoint obtained from the previous phase utilizing either the P-control or PID-control law. This phase enabled the authors to measure the efficiency of their approach in maintaining the desired level of arousal of the player.

c. Results:

The authors have first provided the results from a system simulated using 4 control equations. Simulation results for the open-loop phase show that for higher forward proportionality constant values the increase in the SCR numbers is sharp whereas for lower values of the forward proportionality constant the SCR numbers increase gradually. Simulation results for the closed-loop phase show that for higher values of proportional gain the change in difficulty level of the game is larger (in response to the arousal level of the player) than for the changes in difficulty level using lower values of proportional gain. This causes the issue of arousal oscillation with higher values of proportional gain which can be resolved using a PID controller which the authors have also evaluated in their simulation. The derivative term in the PID controller helps in dampening the oscillations of the control variable whereas the integral term helps in removing residual steady-state error.

In the next section, the authors have provided the experimental results from the open-loop phase where they have observed that the SCR index change is directly proportional to the change in the difficulty level of the game. It is also observed that out of the 3 different mechanics used to control the game difficulty, speed mechanics invoked a higher average and higher variance in the SCR response indicating that speed modality is better than weather or steering modalities.

The authors have then provided the experimental results of the closed-loop phase using the P-control where they found speed mechanics is the most efficient out of the 3 different game mechanics since it had the highest SCR index and smallest standard deviation. Similar results were also obtained using the PID-control in the closed-loop phase and these results were in agreement with the results from the open-loop phase. Also, they found that PID-control performed better in dampening system oscillations than P-control similar to that in the simulation.

Since the results from the simulation and the experimental open-loop and closed-loop phase are consistent, the authors have argued that the control equations used to model the simulation are a valid set of equations that can be used to depict the relation between game difficulty and player arousal. Also, from their results, it can be concluded that speed adaptation is more effective than weather and steering adaptations.

2. **CRITIQUE:**
    a. **Pros:**
        i. The game uses the physiological conditions of the patient to manipulate the difficulty of the game instead of in-game scores which makes more sense for this purpose.
        ii. The research can potentially lead to the development of more engaging games in the future. Changing the difficulty of the game with respect to the physiological conditions of the player will make it more interesting to play.
        iii. Their approach in using control theory to manipulate the varying arousal level of the player to stay at a constant level by manipulating the difficulty of the game based on the electrodermal activity of the player is unique and very effective.
        iv. Their approach in maintaining a constant arousal level of the player can help him/her in improving his performance and attention and in reducing his anxiety levels.
        v. Their approach can potentially help in game development as it helps in simulating the system behavior under different parametric configurations.
        vi. The authors have provided measures that are objective in nature such as error and oscillation for the purpose of evaluating a game which can also be very helpful for the purpose of game development.
        vii. Their approach can also be used to record the oscillations in arousal levels of the player.
    b. **Cons:**
        i. The approach uses sensors that need to be connected to one's body which might prove to be uncomfortable while gaming. Instead, detection of physiological metrics from the facial expressions of the person using computer vision can be seen as a viable alternative approach.
        ii. Only 1 kind of game was used in the experiments.
        iii. The number of participants in the experiments was low which can cause the results to be biased.
        iv. The authors have used only the electrodermal activity to manipulate the difficulty of the game. Several other physiological factors such as heart rate, blood pressure, breathing rate, etc. could have been used.

v. The authors are assuming that there is a direct relation between the mental condition such as stress level and physiological condition such as the electrodermal activity of an individual which might not be true in all scenarios.
vi. The authors have also assumed that an optimum level of electrodermal activity can be observed and that it is possible to control the electrodermal activity of the player to stay at the desired level via controlling the game difficulty.

3. **FOLLOW UP:**
   a. Research can be undertaken to use computer vision for the measurement of the physiological variables of an individual using his or her facial expressions and body movements instead of using wearable sensors.
   b. Different types of games can be used for similar kinds of experiments to find the effectiveness of each kind of game. Also, a similar kind of approach can be used for the purpose of stress reduction and management via bio-feedback gaming.
   c. Other physiological factors such as blood pressure, heart rate, breathing rate, etc., can be taken into account for the purpose of controlling the difficulty of the game and research can be undertaken to measure the efficiency of these different physiological factors in controlling the level of arousal of the player.
   d. The entire set of experimental steps was completed in 1 session. Further research by performing the experimental steps in multiple sessions can be undertaken to check whether similar results are obtained or not.
   e. Event information related to the collision of the car with other objects on the track can also be used to obtain extra information from the arousal response such as the SCRs obtained during events when the player is startled after a collision.
   f. Other types of controllers such as a reinforcement learning controller can be used to learn the relationship between the difficulty of the game and the arousal level of the player and the optimal arousal levels.