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Physiological Computing Gaming: use of Electrocardiogram as an input for Video Gaming

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Abstract

There are several ways of creating a human-computer interaction (HCI) such as physiological computing (PC) i.e. the use of body signals as a real-time input to control a user interface. This research describes the development of a new solution in which electrocardiography (ECG) signals are used as input for video gaming. The solution includes: a tailored belt with conductive textiles as ECG electrodes; a specialized data acquisition board (Bitalino); signal processing algorithms implemented in Python for signal filtering, QRS complex detection and heart rate calculation; and use of Unity 3D, a game development engine, in which the heart rate is used as an input of a proof-of-concept PC video game – FlappyHeartPC.

Introduction

Advances in computation and integrated circuits capabilities allow videogames to be more emotionally engaging. Still, at the moment, these interactions are based purely on the input the player consciously decides to use in the game world (i.e. actions executed through the game controller). However, there are unseen **physiological responses** (e.g. heart rate variations) taking place within the player's body as well as various **behavioral responses** (e.g. gestures, facial expressions, body postures). Such responses are useful in identifying the current **emotional state of the player**. The form of gameplay where this information is collected is commonly referred to as **affective gaming**, in which the **player's emotional state is used to influence gameplay**.

There are three high-level design heuristics for **affective games** (1):

- **Assist me:** Games that detect user frustration and tries to avoid this.
- **Challenge me:** Games adapt the difficulty level accordingly to each player to prevent user boredom.
- **Emote me:** Games that track the user's emotional response to specific game content and adjust subsequent content to achieve a high level of 'dramatic' user experience.

From the perspective of emotion recognition technology, affective gaming is related to **biofeedback systems**, where people 'learn' how to control physiological activity such as blood flow, muscular action, or brain waves by being provided with real-time graphical representations of their biometric state.

The main goal of this work was to test the usability of an **ECG signal in a computer game** called **FlappyHeartPC** (based on FlappyBird™).

Materials and Methods

In the creation of the belt we decided to use **electroconductive textiles** (electrolycra) instead of conventional Ag/AgCl electrodes, which allows the improvement of signal acquisition methods targeting **wearable**, unobtrusive and continuous ECG applications (2).

The prototype belt is also comprised of: elastic rubber-textile material (allows the belt to adhere strictly to the body), non-elastic knitted fabric (assures the same position of the electrodes) and Velcro (fixing to the body and locking), figure 1.

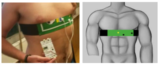

Figure 1. Experimental setting (left) and schematic draw (right) of the belt. The ground electrode is place over the sternum and the electrodes are placed in the 4th intercostal space at the left of the sternum and at the middle clavicular line. The green rectangle correspond to non-elastic knitted fabric and the remaining black strips correspond to the rubber-like elastic material. The belt is connected to the Bitalino board.

For the acquisition of the ECG signal we used the **Bitalino** board, a low-cost platform targeted at multimodal signal acquisition, that can interface with other devices, or perform rapid prototyping of end-user applications in the field of PC, figure 2 (3).

ECG signals were acquired from 2 healthy male subjects.

Figure 2. Bitalino Board (3)

ECG signal processing in Python included:

- Processing of packets of 10 s of data
- Notch filtering (50 Hz)
- Finite Impulse Response filtering
- Low-pass filtering (cutoff 20 Hz, Blackman & Harris window, 61 order), followed by High-pass filtering (cutoff 15 Hz, Blackman & Harris window, 61 order)
- Signal thresholding (30% max amplitude) followed by Low-pass filtering with cutoff frequency equal to 2 Hz and order 100
- **QRS complex peak detection**: differentiation and wavelet-based peak detector algorithms
- Comparison of 3 min ECG recordings
- **Heart rate calculation**

Unity 3D is a game development ecosystem, a rendering engine integrated with a set of intuitive tools and workflows to create interactive 3D and 2D content (4).

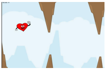

Figure 3. Screenshot of the FlappyHeartPC game.
(background and rocks cc0 license Kenney Vleugels)

For the proof-of-concept of this work we decided to design a PC game named **FlappyHeartPC** in which the heart rate is translated into the speed of the heart game character (figure 3, table 1). The inspiration for this game was the FlappyBird™ game.

Table 1. Player's heart rate and following thresholds for the Units/frame

Hearth rate	<50	50<60	60<70	70<80
Units/Frame	0.5	1	2	3
Hearth rate	80<90	90<100	=>100	
Units/Frame	4	5	6	

The **goal of the game** is to survive as long as it is possible, avoiding collision with obstacles. The gaps between obstacles were chosen randomly. Here, the higher the heart rate is, the faster the game character moves. This makes the game more difficult and therefore it induces the player to maintain a low heart rate level to increase the chances of survival.

Results

During testing we recorded ECG signals using conventional Ag/AgCl and using the belt with electrolycra. Although noiser, the QRS complex is clearly observed using the textile electrodes (figure 4).

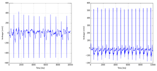

Figure 4. ECG signal recorded by Ag/AgCl electrodes (left) and the belt with electrolycra electrodes (right).

After signal processing and QRS complex detection (figure 5), heart rate was calculated and used as an input into the FlappyHeartPC game.

The **accuracy** of differentiation and wavelet algorithms in QRS detection was 90,6% and 91,4%, respectively, but the former was 8-fold faster (10 s of data in 1.2s) than the latter (10 s of data in 7.8 s). As such, we used the differentiation algorithm in the final version of the game.

Evaluation of gameplay was found to be more challenging.

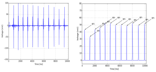

Figure 5. ECG signal after filtering (left) and final example of QRS complex detection (right)

Conclusion

In this work we developed a PC video game based on a setup that includes electroconductive textiles, a low-cost biosignal acquisition platform and ECG signal processing routines. We found that there is room for improvement both regarding the robustness of the belt and the implementation of ECG processing directly into Unity 3D, instead of using Python programming. Probably this could make gameplay even smoother. Although test subjects found the game appealing, larger user samples should be studied.

Future work is proposed, namely the development of a physiological computing function library that can be integrated directly in Unity 3D and therefore boost the development of PC-based video games.

References

(1) Gilleade, K., Dix, A., & Allanson, J. (2005). Affective videogames and modes of affective gaming: assist me, challenge me, emote me. Proc. DIGRA 2005 Conference, pp. 1-7; (2) Silva, H. et al. (2011). Study and evaluation of a single differential sensor design based on electro-textile electrodes for ECG biometrics applications. IEEE Sensors 2011: 1764-1767. (3) Bitalino: http://www.bitalino.com; (4) Unity 3D: http://unity3d.com/