Check Your Biosignals Here: Experiments on Affective Computing and Behavioral Biometrics

Hugo Silva[1]
hsilva@lx.it.pt
Ana Fred[1]
afred@lx.it.pt
André Lourenço[2]
alourenco@deetc.isel.ipl.pt

[1] Instituto de Telecomunicações
Instituto Superior Técnico
Lisbon, Portugal

[2] Departamento de Engenharia Electrotécnica e Telecomunicações e de Computadores
Instituto Superior de Engenharia de Lisboa
Lisbon, Portugal

Abstract

Biosignal analysis has far exceeded the medical practice scenarios to which it was traditionally associated with, to find novel applications in areas so diverse as e-learning, sport sciences, entertainment, among many others. The growing interest by both research communities and industry leaders throughout different activity sectors, together with the profusion and usability of modern acquisition technologies, has enabled a true revolution in the field of biosignal research. However, a problem that researchers normally face, is the access to large sets of data, in particular collected in a repeatable manner. This paper presents a data acquisition framework and experimental setup, designed to further extend our research in the areas of affective computing and behavioral biometrics. Initial experiments, targeted the analysis of relatively unexplored aspects related to the acquisition and processing of SCR and ECG signals, from which preliminary findings revealed new research opportunities.

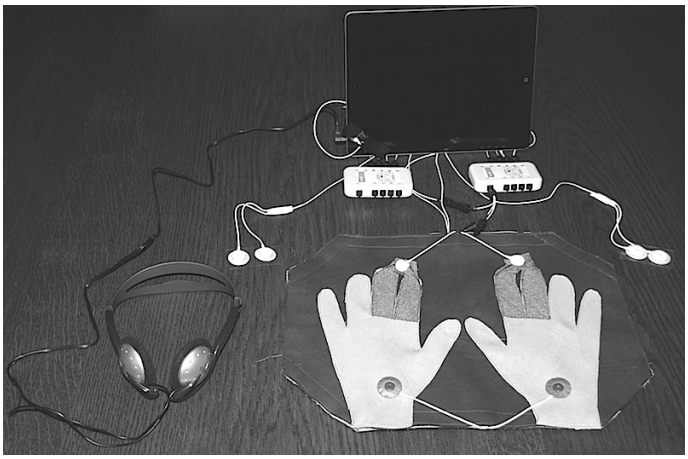


Figure 1: Biosignal acquisition setup.

1 Introduction

Affective computing, and behavioral biometrics are two areas in the bleeding edge of novel applications for biosignal technology. The former deals with computational processess associated with the emotion and related affective phenomena [6], while the later focuses on identity recognition based on physiological or behavioral properties of individuals as a complement to the physical traits that are traditionally used [8].

Previous work from our group has started research in each of the fields [1, 3], which continues to be further developed with quite promising results [2, 4, 5, 7]. A particularly important aspect is the access to large data sets, to evaluate the robustness of the devised methods to changes in the environmental conditions, aging, and other factors surrounding the subjects. In this paper, we describe a data acquisition framework and experimental setup, devised to collect data from a wide group of subjects through an easily repeatable and efficient procedure.

Our purpose is to create a set of databases for assessment of the variability of biosignals throughout time. Initial experiments targeted the acquisition of Skin Conductance Response (SCR), and Electrocardiographic (ECG) signals. The objective of our study was to identify new research leads within the field of affective computing, namely around the concepts of SCR laterality and SCR pulse latency, and to further extend our research in the field of behavioral biometrics through the use of ECG signals collected at the hand palms and fingers.

2 Experimental Setup

Given the requirements of our study, the following outcomes were expected in terms of data acquisition: a) simultaneous recording of SCR signals on the left and right hands, to evaluate laterality; b) simultaneous recording of SCR signals on the thenar eminence and fingers, to analyze SCR pulse latency; and c) ECG data acquisition at the hand palms with dry Ag/AgCl electrodes and at the fingers with Electrolycras, to assess the biometric potential of signals collected at these anatomic regions and compare the performance of both materials.

Figure 1 depicts the hardware configuration of our experiments, for emotion elicitation and biosignal acquisition. To promote emotional responses on the tested subjects, an Apple iPad 2 was used to display and reproduce multimedia content; headphones were also used, to provide greater focus on the reproduced content and maximize the impact of the prepared stimuli.

For SCR data acquisition, two edaPLUX electrodermal activity sensors were used, that have a $3Hz$ analog low pass filter and input impedance $> 3TOhm$. ECG data acquisition was performed with a custom, two lead differential sensor design with virtual ground, gain 4000, $1-30Hz$ analog bandpass filtering, CMRR $110dB$, and input impedance $> 100MOhm$.

Two ECG sensors were used, one for signal acquisition at the hand palms with dry Ag/AgCl electrodes, and another for signal acquisition with Electrolycras at the index and middle fingers. For improved comfort and greater efficiency, the ECG sensors were fitted to a leather base, with the intended hand placement signaled in an unequivocal way.

Data Acquisition was performed with the bioPLUX research, Bluetooth wireless biosignal acquisition unit; this device was used in a 12-bit resolution, $1KHz$ sampling frequency configuration. To guarantee electrical isolation between both edaPLUX sensors, and both ECG sensors used in the experiments, two independent biosignal acquisition units were used, one for each edaPLUX/ECG sensor pair.

Time synchronization between both units was performed optically to ensure ground decoupling, using elements from a syncPLUX synchronization kit. To one of the units, we connected a switch, which simultaneously activated a light emitting diode (LED), and triggered a TTL signal to the digital input port of the device; to the other unit, we connected a light dependent resistor (LDR), which was glued to LED. With this setup, whenever the switch was pressed, a common signal was recorded by both devices, enabling time alignment in the post-processing.

A second synchronization mechanism was also implemented using LDR sensors, to guarantee synchronization between the biosignal acquisition units and the multimedia content displayed. For this purpose, two LDR sensors were applied to the iPad screen, one connected to each of the biosignal acquisition units. In a pre-test stage, the videos were played to capture a videoprint based on the screen light intensity variations, which allowed us to relate the biosignals activity with the stimuli being presented.

Furthermore, this mechanism allowed us to introduce redundancy in the synchronization process, as the information extracted from the videoprints alone can be used for time alignment of the signals collected by each independent unit. Since the operating principle of the LDR sensors is also optical, electrical decoupling between both independent units is once again guaranteed. In the post-processing stage, videoprints from each of the sensors can be matched using for example a MSE criteria.

3 Methodology

The experimental setup was placed on an unrestrained setting, in the main entrance of the building where our research group is located. The iPad, sensors, and biosignal acquisition system were placed on a table, together with the base stations for real-time data recording, in an arrangement where the subject sat on one side of the table, and the experts on the other side. Subjects participated in a volunteering basis, under the compliance of an informed consent explaining the purpose of the study, and authorizing the anonymous use of the data.

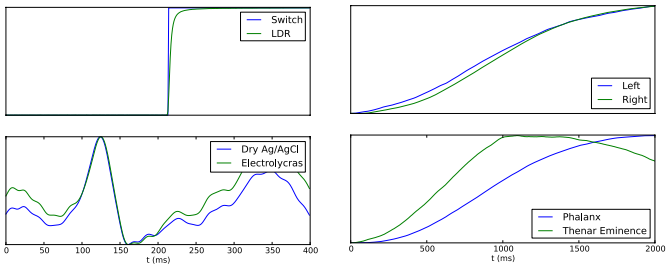
The whole experiment was designed to have an average total completion time of approximately 5 minutes, scattered throughout three stages: 1. informed consent; 2. neutral video stimuli; and 3. intense video stimuli. Once participants willingly showed interest in becoming part of the experiments, the first stage would take place, and consisted on having the expert going through the informed consent, explaining the procedure in detail, goals of the study, and related background work. During this phase, only ECG signals at the hand palms and fingers were recorded.

For second stage, subjects were fitted with SCR sensors on the left and right hands, in each of which one terminal of the sensor was placed on the middle phalanx of the index finger, and the other on the middle phalanx of the ring finger. The headphones were placed over the ears, and a neutral/amusing video was started on the iPad. During this phase, ECG signals at the palms, and SCR signals from the left and right hands were recorded.

For the third stage, the SCR sensor from the right hand would be removed, and placed over the thenar eminence of the left hand, with the electrodes 2*cm* apart, and aligned midway between the muscle insertion point and its origin, at the muscle belly. The headphones were kept on the subject, and the video on the iPad switched to a video sequence with an intense stimuli. During this phase, ECG signals at the hand palms, and SCR signals from the thenar eminence and fingers of the left hand were recorded.

At each stage, recordings from each individual device were stored in a separate file for more efficient post-processing and labeled with the date, identification of the system, and initials of the subject name. In the beginning and in the end of each recording, the switch would be triggered in order to produce the synchronization signal, necessary to find the common time base as previously described.

The initial experiments took place over two full days, and in the end data had been collected for an overall total of 65 normal participants (49 males, and 16 females), with an average age of 31.1 ± 9.46 years.



(a) Optical synchronization (top) and ECG signals (bottom).

(b) SCR signals of laterality (top) and pulse latency (bottom).

Figure 2: Examples of the signals extracted from our initial experiments. All signals are normalized for improved legibility.

4 Preliminary Results

Several interesting indicators arose from the signals collected with our initial experiments. Figure 2 depicts all of the collected biosignals, grouped according to the area of application, and normalized for improved legibility. As shown in Figure 2(a) (top), the optical synchronization method enables time alignment within the millisecond, allowing the signals collected by each independent unit to be compared in the same time base.

Regarding the tests targeting affective computing studies, SCR laterality analysis revealed that, for normal individuals no meaningful latencies are detected between the left and right sides; amplitude however exhibits a different behavior. Figure 2(b) (top), shows a SCR signal sample from the laterality tests. The most evident finding from the SCR tests is shown in Figure 2(b) (bottom), where an example of the SCR pulse latency analysis is presented. In this case, a time difference between the detection of a SCR pulse at the thenar eminence and at the phalanx is clearly and consistently noticed.

Further research is therefore required to better characterize these findings both in normal population and other population groups, as they may conceal additional information regarding the subjects affective or cognitive state of the subjects. Being related to the sympathetic nervous system, indicators extracted from the SCR signals may be particularly useful for easy and non intrusive assessment of the efficacy of pharmacological treatments.

On the behavioral biometrics component, several relevant findings were also extracted from our tests. As shown in Figure 2(a), both the ECG signals collected at the hand palms and at the fingers, provide an adequate level of details. In particular, not only the so-important QRS complex is clearly noticeable, but also the P and T waves can be found. Moreover, we can see that the dry Ag/AgCl and the Electrolycras are very well correlated in terms of their waveforms, leading us to believe that either of these can be used as interface with the skin, giving higher flexibility and convenience to the biometric system designer.

5 Discussion and Future Work

We have described a biosignal acquisition framework, devised to overcome the need for a repeatable and easy to apply procedure for data collection in large population groups. This setup builds upon prior work from our group in the area of biosignal research, as a tool to identify potentially time variant properties in the signals, and to evaluate the robustness of algorithms and methods to changes in the environmental conditions and other data acquisition influencing factors.

Initial experiments were performed in two highly active domains within the biosignal research field, namely affective computing and behavioral biometrics, with the purpose of looking into relatively unexplored aspects within these fields, as SCR laterality and pulse latency, and evaluation of the biometric potential of ECG signals collected at the hand palms and fingers using different materials.

Preliminary results provided valuable insight on the addressed topics, and prove the need for further validation and study. The next steps of our work in this topic will be focused on rewarding the volunteers by sending feedback artwork generated from their signals, making a recall of volunteers for a repetition of the experiments around month four after the first session, and making the collected biosignals databases available on-line for other researchers in the field.

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