Palm-based ECG biometrics

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Abstract

We propose an experimental apparatus for ECG biometrics, that matches the usability and intrusiveness levels of traditional biometric traits like fingerprint or hand geometry centered on subject's hand or fingers, and that require some degree of contact of proximity to the sensoring device. A hardware device was developed, comprised of a surface with integrated electrodes and signal conditioning circuitry, where the subject rests his/her hand palms, allowing the signal acquisition without the need for conductive gel nor access to more intimate parts of the body. Preliminary results show that this setup led to competitive results matching recognition rate of ECG signals acquired at the fingers.

1 Introduction

Electrocardiographic (ECG) signals are a recent trend in biometric recognition. It has very appealing characteristics, as intrinsic liveliness detection, and not depending on external physical landmarks, therefore being more difficult to spoof.

Traditional biometric traits like fingerprint or hand geometry, are already centered on subject's hand or fingers. For fingerprint, the subject needs to place or scroll the finger in the reader, and for hand geometry the subject needs to place the hand on the reader. The usage of hand/finger is thus an already familiar procedure for the user.

In the pioneer work by Biel *et al.* [1] a 12-lead setup was used to acquire the ECG signal mounted on the chest and limbs with pre-gelled electrodes or conductive paste to improve conductivity with the skin. More recently [4, 6, 7], it was shown that a 1-lead setup suffices. The sensing apparatus has also evolved, changing from acquisitions performed on chest with pre-gelled electrodes, to a non-intrusive and more practical acquisition at the fingers [4].

In this work we further explore the experimental apparatus presented in [4], proposing a new acquisition setup, which reduces the number of contacts required for the acquisition of the ECG to only two measurement leads. This is acomplished based on a new single differential sensor design [8] that does not require the traditional ground lead. The proposed setup enables the acquisition of ECG using index and middle fingers, and using hand palms. This setup is substantially more comfortable than previous ones, enabling people to use it in their daily routines.

2 Proposed Approach

We propose an experimental apparatus for ECG biometrics, that matches the usability and intrusiveness levels of conventional biometric systems. Our device is comprised of a surface with integrated electrodes and signal conditioning circuitry, where the subject rests his/her hand palms, allowing the signal acquisition without the need for conductive gel nor access to more intimate parts of the body.

The system can either be used with Ag/AgCl electrodes or Electrolycras as interface between the sensor and the skin for improved usability. Furthermore, a custom signal conditioning circuit was developed, which only requires two contact points with the skin, through the use of a virtual ground. This design, improves upon prior art work, as traditional ECG sensors require positive (+) and negative (-) poles, together with a ground (GND) lead. With our design, only the (+) and (-) leads are required.

Figure 1, depicts the proposed setup. In this configuration, and for experimental validation purposes, the device allows the acquisition of ECG signals at the hand palm through dry Ag/AgCl electrodes, and at the index and middle fingers through Electrolycras.

Figure 1: Experimental apparatus: at the top Electrolycras enable the acquisition of ECG using the index and middle fingers; at the bottom dry Ag/AgCl electrodes acquire ECG at the hand palms.

As scenario of application consider the adaptation of the setup on a keyboard, allowing that the ECG is being continuously acquired at the hand palms, while the user is typing, as illustrated in figure 2. We will show that this setup can lead to high performance rates, and thus that it can be used to improve protection in high security applications. Moreover, instead of regular electrodes, dry Ag/AgCl electrodes are used on the acquisition, further improving the usability.

(a) Setup adapted to Keyboard (b) User typing

Figure 2: Example of adaptation of the purposed setup for the context of continuous biometrics based on the ECG acquired at hand palms.

3 Experimental Evaluation

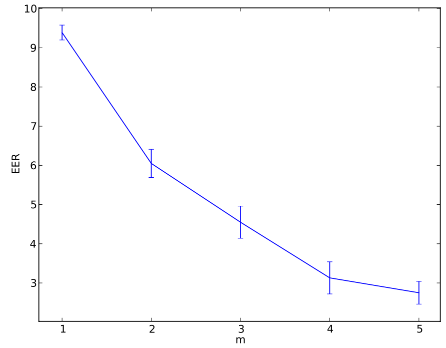
To evaluate the experimental setup, we performed an extensive data collection in 32 subjects (25 males and 7 females) with an average age of 31.1±9.46 years. Subjects were only asked to rest their left/right hands as indicated in the device.

Two custom ECG sensors [8] were used for signal acquisition, with total gain of 1000 and analog band pass filtering between the 1-30Hz range. In Figure 1 both sensors are visible, one connected to the Ag/AgCl electrodes, and another connected to the Electrolycras strips placed at the finger level.

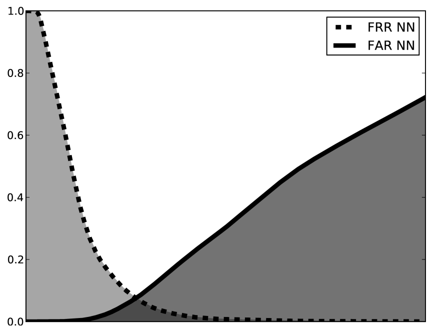
To guarantee electrical insulation of the sensors, two independent biosignal acquisition units were used, one per sensor. We recurred to the bioPLUX research system [5], which enables Bluetooth wireless transmission of the collected signals to the base station. Synchronization of the acquisition units was performed optically using a syncPLUX kit and a light-dependent resistor (LDR). To one of the systems a triggering switch was connected, which simultaneously activated the digital input port of the system and an light-emitting diode (LED). To the other system, a LDR was connected to one of the analog input channels. This allowed us to have the data collected by each system synchronized, without recurring to any electrical connection between them. Signals were acquired during a period of approximately 2 minutes, during which the supervisor would describe the experiment and related work.

The processing of this signal consisted in a filtering step using a band-pass with 1-30Hz frequency span and passed a segmentation step using a QRS-complex detection algorithm based on the commonly used Englese and Zeelenberg algorithm [2]. Heartbeat waveforms are then segmented and the mean waves computed in order to obtain a representative wave template pattern of the subjects ECG. We evaluate the performance of the system using a varying the number of segments, m, used to compute the mean wave.

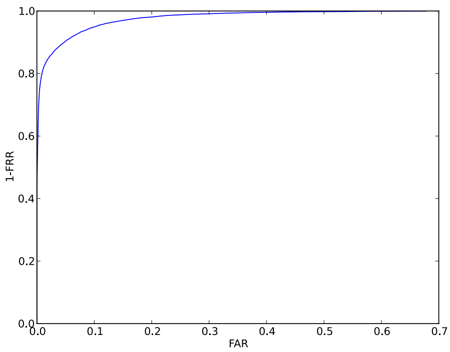
For evaluation purpose, a 30-fold cross validation was implemented; runs with two randomly selected exclusive datasets were created with the training set containing 30% of the total collected segments as the templates database, and a test set with 70% of the remaining segments.



(a) EER



(b) FAR-FRR



(c) ROC

Figure 3: Equal Error Rate (EER) as a function of m, the number of segments used to compute the mean; FAR and FRR curves and ROC curve in an authentication scenario (for m=5).

Figure 3(a) shows the Equal Error Rate (EER) for authentication varying the number of segments used to compute the mean wave: if $m = 1$, one individual heartbeat waveforms is used, a mean EER of $9.39\% \pm 0.19$ is attained, which decreases to $2.75\% \pm 0.29$ when $m = 5$. These correspond respectively to approximately $1s$ and $5s$ of acquired signals. Figure 3(b) illustrates the false acceptance rate (FAR), and false rejection rate (FRR), when using $m = 5$, which are obtained using different operating points of the classifier. The EER corresponds to the intersection of those two curves. The receiver operating characteristic (ROC curve) is presented in Figure 3(c).

These obtained results are within the confidence intervals of other studies in literature [3, 4, 6, 7]. In authetication scenarios, using chest and finger signals, results are in the order of $\sim [2-5]\%$.

4 Conclusions

The field of application of electrocardiographic signals is expanding to new areas which far extend the medical and quality of life applications to which it is typically associated with. Biometrics is currently emerging as one of these novel application fields.

Within the scope of biometric recognition, conventional acquisition apparatuses have specificities which limit the acceptability by the potential end-users. This arises from the fact that, in general, devices require pre-gelled electrodes to acquire the signals, but more importantly, because they need to be applied to the subjects body.

In this paper we presented an experimental setup, proposing ECG acquisition at the hand palms. Furthermore, our approach recurs to a custom two-lead ECG sensor, that can use either dry Ag/AgCl electrodes or Electrolycras as interface with the skin. For signal acquisition, the user only needs to rest his/her hand over the sensors without any other constraint.

Experimental results have revealed that the collected signals provide adequate informative content reaching a mean EER of $2.75\% \pm 0.29$ when averages of 5 heartbeat waveforms are used, which constitutes a promising alternative for conventional biometric systems.

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