A Unifying Approach to ECG Biometric Recognition Using the Wavelet Transform

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Abstract. Biometric recognition systems use measures from the body itself to determine the identity of an individual. The electrocardiogram (ECG) has been increasingly used as a biometric measure for person identification, as it is an easily measurable characteristic of all individuals. Our method for ECG acquisition follows an off-the-person approach, using a single ECG lead with non-gelled electrodes placed at the hands. However, this signal is noisier than typical ECG signals acquired on the chest, making subsequent processing more difficult. Therefore, we investigate the applicability of the Wavelet Transform (WT), which decomposes a signal into a time-scale representation according to a given mother wavelet. We use this representation to both segment the R wave of the ECG signal, and as the features for the classification step, defining an appropriate distance measure. We test this framework with real data, using various mother wavelets. Our experimental results show the potential of this framework, and that the best mother wavelet for the evaluated context is the *rbio5.5*.

Keywords: Biometrics, ECG, Wavelet Transform, QRS detection, Wavelet Distance.

1 Introduction

Biometric recognition systems use measures from the body itself to determine the identity of an individual, such as DNA sequencing, fingerprint analysis, speech recording, among many others. The performance of these systems, which are indispensable for security applications, varies greatly in what concerns the invasiveness of the biometric measurement, the recognition accuracy, and the robustness to fraudulent attacks.

The electrocardiogram (ECG) has been proposed as a biometric measure for person identification [1], complying with several of the design requirements defined in Jain *et al.* [2]: Universality, Measurability, Performance, Acceptability and Circumvention [3]. A review of the current research in ECG biometrics has been recently made by Odinaka et al. [4]. Our previous work on this topic has focused on the intrusiveness level of the sensor device, which was a limiting aspect of this modality. In [5] we presented a new acquisition apparatus consisting of a single ECG lead, with a simplified setup comprised of two non-gelled

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electrodes placed at the hands, entitled off-the-person approach. This approach has multiple advantages, one of which being the possibility to easily acquire the ECG signal. However, the resulting signal-to-noise ratio is extremely low when compared to that of a signal acquired on the chest. In this context, we studied the applicability of the Wavelet Transform (WT) as a tool to process the ECG signal for biometric applications. The WT, which provides a powerful time-scale representation framework for complex non-stationary signals, has already been applied successfully to ECG signals, with the purpose of filtering, segmentation of the P, Q, R, S and T waves, and for arrhythmia detection [6]. For biometric recognition, the WT has been individually applied as a filtering and segmentation tool [7], as a feature extraction method [8], and as a distance measure between template signals [9]. In this paper we present a unified framework in which the entirety of the processing steps are made with the Wavelet Transform. In particular, the WT is used to decompose the raw ECG signals into a time-scale representation, on which segmentation of the R wave is performed. The time-scale representation is also used as the features for the classification step, using as distance measure the one proposed in [9]. This framework is tested with real data using our in-house database, and the results are compared with the previous approaches.

The remainder of this paper is organized as follows: Section 2 presents in more detail the Wavelet Transform and its properties, Section 3 describes the methodology used for the biometric recognition system, which is evaluated in Section 4, and Section 5 concludes the paper with a discussion of the main results.

2 Wavelet Transform

The Fourier Transform (FT) has established itself as one of the most essential tools of signal processing, providing easily interpretable results, and computational efficiency with its FFT algorithm. Nevertheless, it has some practical drawbacks. In particular, it has no temporal resolution and the frequency resolution is determined by the window size. As a result, time-frequency signal analysis based on the FT, such as the Short-Time Fourier Transform (STFT), is flawed by the compromise between temporal and frequency resolution. The Wavelet Transform (WT) has been suggested as a more robust alternative to the STFT, with increasing popularity [10,6]. With the WT it is possible to simultaneously capture short duration, high frequency and long duration, low frequency information, which is especially useful for the analysis of non-stationary signals, such as transients or aperiodic signals [6]. The Continuous Wavelet Transform (CWT) W of a continuous-time signal $x(t)$ is given by:

$$W_\psi(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} x(t)\, \psi^* \left(\frac{t-b}{a} \right) dt \tag{1}$$

where $(.)^*$ is the complex conjugate operator. The main idea behind the WT is similar to the FT, but here the basis functions are not restricted to sinusoids,