Development of a New Biometric Authentication Approach Based on Electrocardiogram Signals

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***Abstract*— Current research shows that one of the best methods for authenticating human beings is biometrics. In this paper, the heartbeat biometric, also called Electrocardiograph (ECG), is proposed. The heartbeat biometric is chosen because the ECGs is unique. The purpose of this study is to find the best biometric features that able to identify a person, given the extractions and classification algorithms for the heartbeat biometric signal. Depending on a literature study, we proposed a new more efficient technique based on the wave modeling of the ECG signal for features extraction where this features is used as an inputs for pattern recognition classifier. This proposed methodology is tested on a real experimental ECG data, the processing of ECG signals must include signals acquisition, signal filtering & pre-processing using the most familiar and multipurpose MATLAB software. The results obtained are very accurate feature compared to features extracted from classical parameters. Therefore, the wave modeling for extracting features is the most efficient and accurate way to obtain the best results in classification. As for future work, automatic heartbeat classification is essential for real-time applications to identify person.**

Keywords: Biometrics, Electrocardiogram, Heartbeat Recognition, Waves Modeling

I. INTRODUCTION

Today, life engages technology in multiple ways, thus authentication in human technologies is very important. Secure and reliable authentication is in high demand. However, traditional methods for authentication such as face recognition, voice recognition and passwords are now outdated because faces are available in social media and couldn't differentiate between two twins, and voices can be easily recorded from calls. However, ECG signal is a universal characteristic [1]. The Electrocardiogram (ECG) is the recording of electrical activity of human heart using electrodes placed on the skin over a period of time. The shape of the waveform reveals the current state of the heart and it offers helpful information regarding the rhythm and function of the heart. There are 3 main components to an ECG: P wave, QRS complex and T wave [2]. Recently, the possibility of using this ECG signal as a biometric tool has been suggested because the composition and activity of the human heart is unique, stable, easy to collect, have a high performance and it's socially accepted. Its validity is well supported by the fact that both the physiological and geometrical differences of the heart under different subjects reveal certain uniqueness in the signal characteristics due to existing differences in morphology among individuals.

II. MATERIALS AND METHODS

A. *DATA ACQUISITION*

The ECG data used in this research is obtained from real experimental data. The total number of person is 10 subjects recorded over 210 seconds long. The subjects are 6 men aged 20-30 years and 4 women aged 20-25 years. The ECGs were recorded via a commercial ECG device (500 Hz as sampling rate and 500 dB for gain). The number of recordings for each person are obtain from ECG lead 1. In this step signal is being acquired and stored in database, which is further used by system for identification purposes.

B. *DATA PRE-PROCESSING*

ECG data collected usually contain noise. Due to presence of noise the feature extraction and classification becomes less accurate. To prevent misclassification, the ECG data must be processed. The first step must be to identify the noisy sources [3]. In this research, a cascaded digital filters configuration (empirical mode decomposition, low pass filter, high pass filter and derivative base filter), as shown in figure 1, is used for removal of three major noises of baseline drift, power line interference and EMG noise.

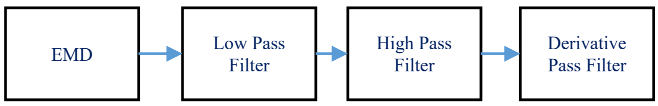

Figure 1: Block Diagram of Data Pre-Processing

EMD is a decomposition technique that allows to represent a signal through the sum of functions derived from the latter, called Intrinsic Mode Function (IMF). The individual IMFs are obtained through a sifting operation. This is an iterative operation. The basic steps to achieve decomposition in IMF are:

a. Identify local extremes. Especially, the maximum and minimum local values of the signal must be evaluated separately.
b. Evaluate the upper and lower envelope of the signal through the application of a cubic spline

interpolation function of the data obtained in the previous point.

c. Compute the mean envelope, obtaining m. Then subtract the mean from the input signal.

d. Evaluate a term condition. If this is respected, then the difference between the input signal and m is the IMF and the next one is evaluated considering as a signal the difference between the input one and the IMF obtained. Otherwise, the process on the residual is repeated [4].

Figure 2 shows a block diagram of the algorithm of EMD

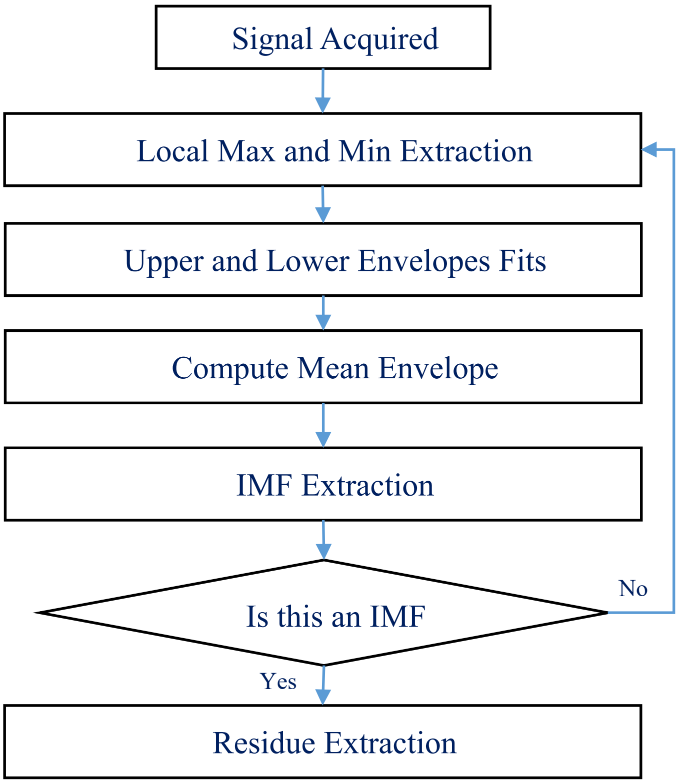

Figure 2: EMD Algorithm

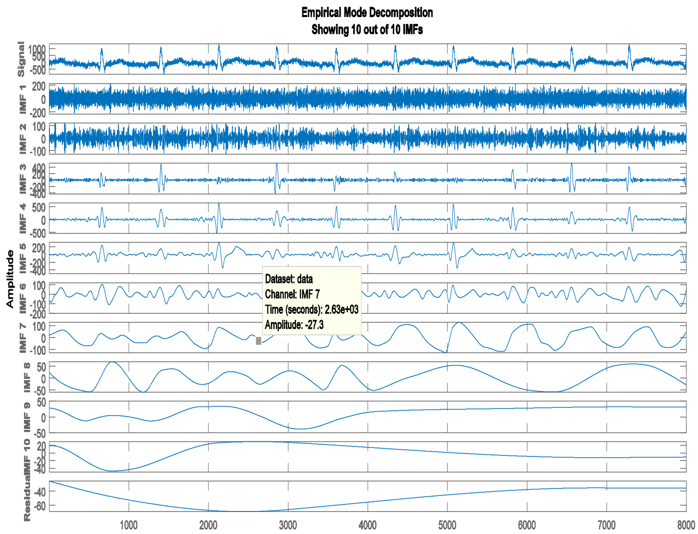

Figure 3: EMD Mode Decomposition

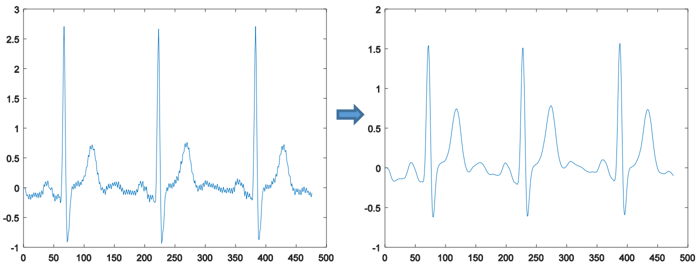

Figure 4: Results of Data Pre-Processing

III. METHODOLOGGY

After demonizing the signal, the data is then divided into train and test sets as shown in figure 5:

i. In training phase: 70% of the filtered data is used as the training samples for classification.

ii. In testing phase: 30% of the filtered data is use as testing data for validation.

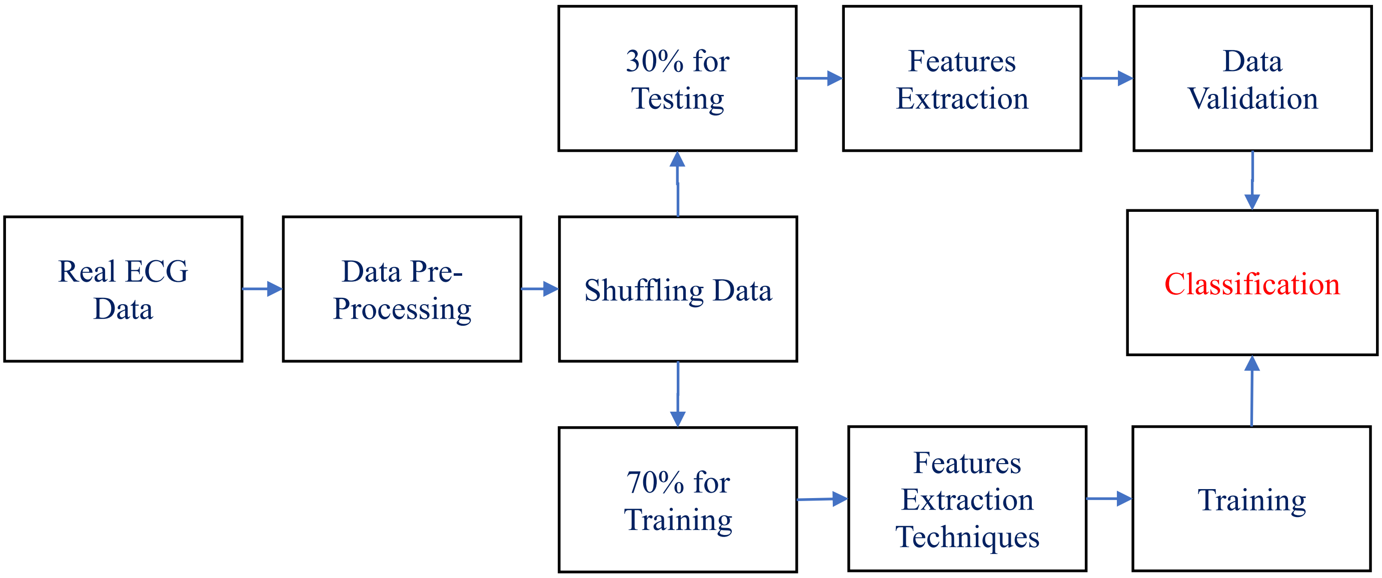

Figure 5: Methodology

A. *FEATURE EXTRACTION*

The feature extraction stage is the key to the success in the heartbeat classification using in the ECG signal. The feature can be extracted in various form directly from the ECG signal's morphology in the time domain and/or in the frequency domain or from the cardiac rhythm.

Figure 6 shows the block diagram of the proposed methodology.

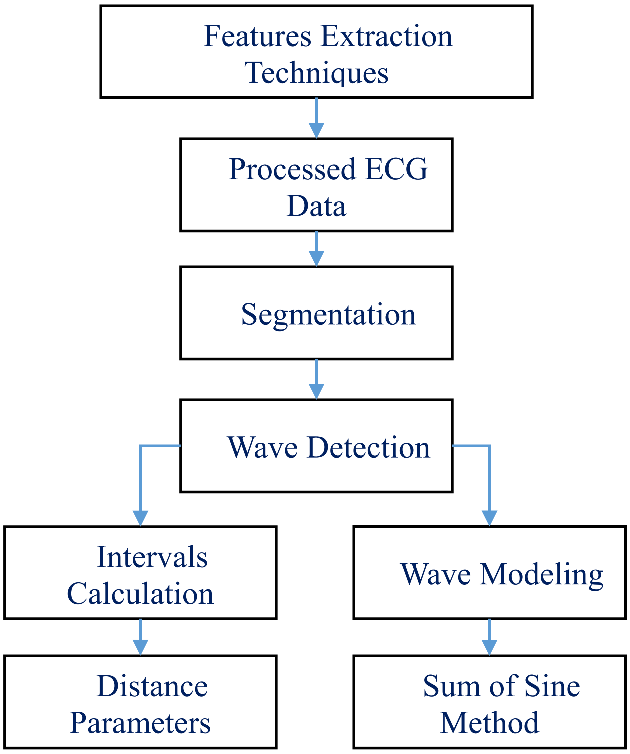

Figure 6: Block Diagram of Features Extraction

1) **Peak detection:** The third step is detection of peaks locations and boundaries of three types of waves, P wave, QRS complex, and T wave which are used in heartbeat signals [1]. Generally, in ECG, the major characteristic wave is R-peak because it has the higher amplitude. After finding R-peak location, other components P, Q, S, and T are detected by taking R-peak location as reference and tracing from R peak relative position as shown in figure 7.

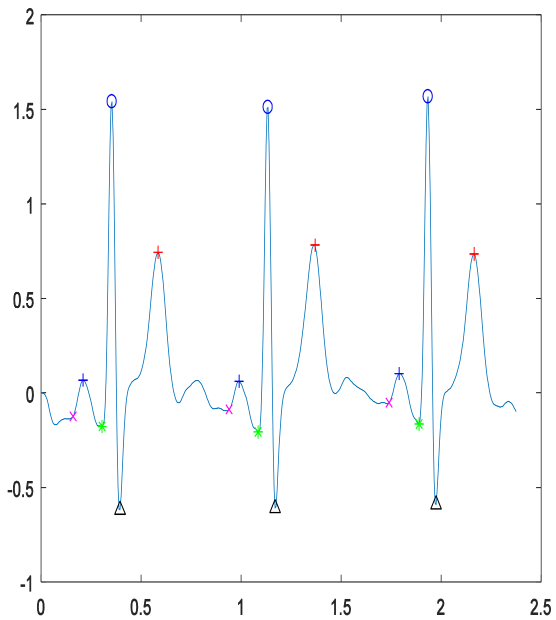

Figure 7: Peaks Detection

2) **Segmentation**: After identifying the points, ECG waveform is segmented into individual heartbeat, as shown in figure 8, and decomposed as a form of sine wave, as shown in figure 9.

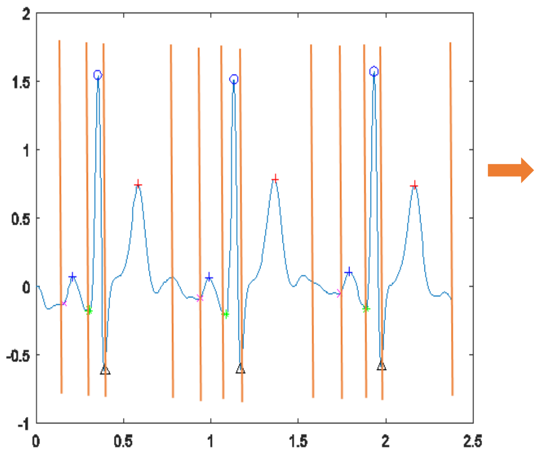

Figure 8: ECG Wave Segmentation

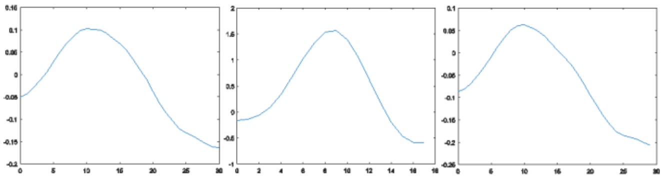

Figure 9: P, QRS and T Waves

3) **Wave Modeling:** The purpose of the feature extraction is to have identical model from same user and different model from different users. This is one of the main step of biometric heart beat because a vector features will be composed and extracted from heartbeat signals as input. We use "cftool" in Matlab to choose the best model of curve fitting and then we generate the code. (1) shows the general model of sum of sine method with degree 5 that is used for modeling.

$$f(x) = a_1 \sin(b_1 x + c_1) + a_2 \sin(b_2 x + c_2) + a_3 \sin(b_3 x + c_3) + a_4 \sin(b_4 x + c_4) + a_5 \sin(b_5 x + c_5) \quad (1)$$

where a_i, b_i, and c_i are the coefficient that are used as an input for artificial neural network.

B. *Biometric Template in Database*

In this step, the vector features of each individual is stored in database. Then the stored data is compared with the entered data from testing phase to identify person for decision making [1].

IV. *Classification*

Classification is used to classify entered data in different set of classes that would be easy to compare with stored data. There are different methods for classification [1]. In this study, the biometric identification is done by feeding the input data of ECG features to an Artificial Neural Network (ANN) [6]. At the primary stage the neural network has to be trained with the ECG data of different persons. Then afterwards the neural network generated from the training is used for biometric identification of the persons.

Figure 10 shows the architecture of neural network that is composed by features as an input, hidden layers and output that identify the person.

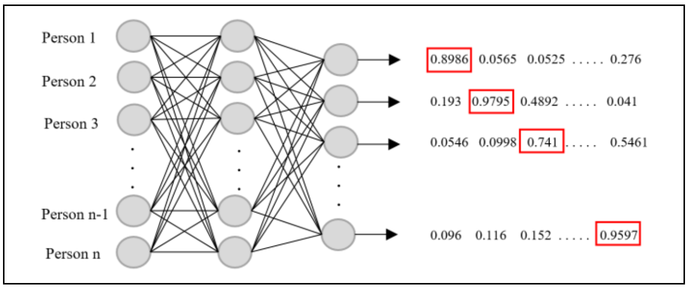

Figure 10: Neural Network Architecture

V. Results & Discussions

The proposed work concentrates mainly on effective feature extraction algorithm that depends on extracting features based on the waves modeling of each heart beat in ECG signal then the feature set is examined by ANN for Pattern Recognition classifier. The results obtained are very accurate feature compared to features extracted from classical parameters (P, Q, R, S and T peaks), which change per physiological and mental conditions such as stress, excitement, exercise, and other diseases like arrhythmia and tachycardia that may change the heart rate [5]. The changes in the heart rate accordingly vary the features such as RR interval, PR interval, and QT interval that contributes to misclassification. Therefore, the wave modeling for extracting features is the most efficient and accurate way to obtain the best results in classification.

Table 1: Person Identification

Person 1	Person 2	Person 3	Person 4	Person 5	Person 6	Person 7	Person 8	Person 9	Person 10
0.8986	0.1930	-0.0546	-0.0038	0.0525	-0.1511	-0.2562	0.1101	-0.1610	0.0969
0.0565	0.9795	-0.0998	-0.1362	-0.0363	0.0490	0.4904	0.1484	-0.0861	-0.1160
0.0525	0.4892	0.7410	0.0594	-0.0261	-0.0341	-0.0292	0.2508	0.0368	0.1528
-0.4946	0.2794	-0.1321	0.9630	-0.2003	-0.2190	-0.2978	-0.0029	-0.1777	0.1026
-0.2387	0.3842	0.3328	0.4321	0.8988	-0.0889	-0.1671	0.4059	0.4261	0.3866
0.5155	-0.0391	0.7948	-0.0461	-0.2757	1.0601	-0.4576	0.1535	0.4707	-0.3215
0.6869	0.2660	0.2632	0.3088	0.1094	-0.0975	0.9116	0.0501	0.1108	0.2601
-0.3317	-0.2886	0.2861	0.0415	0.0492	0.5488	0.3522	0.9676	0.1969	0.0779
0.3462	0.3278	-0.3552	-0.1480	0.5390	-0.3638	-0.0972	-0.1982	0.9271	0.1539
-0.2762	-0.0410	0.5461	0.1660	-0.4422	0.4745	0.1095	0.4457	-0.1123	0.9597

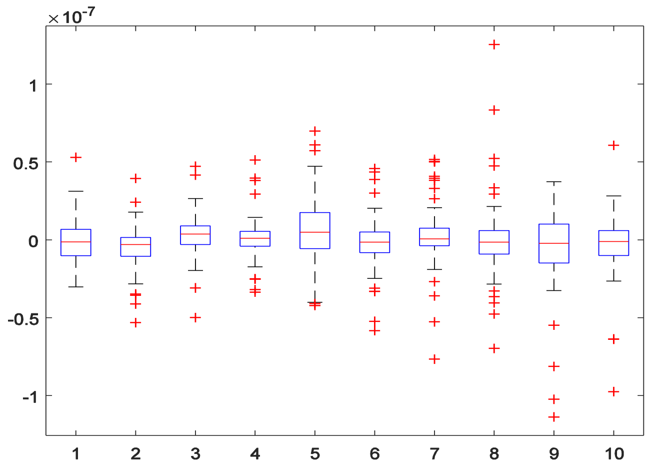

Figure 11: Classification Error Boxplot

Figure 11 illustrates the boxplot, which shows the difference between the mean and classification error. It clearly shows that the error between the real and desired output is negligible (in order of 10^{-7}). This proves that the proposed methodology is able to classify between persons.

The target or output vector is a 10-element vector with a '1' in the position of the classified and '0' everywhere else as shown in table 1.

The multi-layer feed forward neural network able to find the solution after 8 epochs with learning rate mu=0.001.

VI. Conclusions & Recommendations

ECG being none mimic able can more accurately identify a person and can offer more robust and effective human identification system. In order to provide more accuracy in identification and verification process of individual, this paper provides an overview of major steps in ECG signal analysis of de-noising ECG, characteristic points identification, feature extraction and effective feature extraction finally classification. The review recognized different methods of extracting features of the heartbeat signals and compared based on the accuracy result. A good feature extraction methodology can accurately work for biometric applications.

Automatic heartbeat classification is essential for real-time applications to identify person. The obtained results of this research suggest that there is a possibility growth of future in automatic ECG classification systems. Therefore, the heartbeat biometric system compares the information which is collected after Data Acquisition, Pre-Processing, Segmentation, Feature Extraction, and classification steps with data in storage to make the final decision. Then the system will accept or deny individual.

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