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Review of Fiducial and Non-Fiducial Techniques of Feature Extraction in ECG based Biometric Systems

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Abstract

Background/Objectives: Biometric is a tool of measuring and statistically analyzing biological data. Due to advancement in technology, spoofing attacks and credential forgery are becoming very common issues of modern societies. **Methods/ Statistical Analysis:** Over the last decade, the Electrocardiogram (ECG) is known as an emerging biometric instrument for individual identification and verification as the ECG varies among people because of their diverse anatomy of the heart. At present ECG is a popular research topic in the area of physiological biometrics. The greater part of ECG biometric literature employs fiducially based features, resulting from spikes, crest and temporal marker of ECG signal. **Findings:** The main focus of this review is to provide scientific analysis and comparison between fiducial and non-fiducial techniques of feature extraction especially in terms of efficiency in large and small datasets. It also provides a key manifestation of future research perspectives in the field of ECG based biometrics. **Application/Improvements:** The proposed review can be useful in further research in the same area.

Keywords: Biometrics, ECG, Fiducial, Non-Fiducial, QRS-Complex

1. Introduction

ECG signal is a measurement of small voltage change on body of the subject. This voltage change is linked with the trigger and recharge of heart muscles during cardiac activity. In 1924 a Dutch analyst Willem Einthoven first revealed the mechanism of ECG and Nobel Prize awarded to him for his work[1]. Although every individual have the same prototype of heartbeat as shown in Figure 1, but comprehensive analysis shows quite variance among the heartbeats of different people. Therefore, it is anticipated that ECG signals of every individual possess distinctive features.

Due to rapid advancement in technology our daily life is becoming more dependent on automatic and accurate identity proof systems. At present, credentials forgery is main fault of the conventional biometric techniques. Tokens, smart cards, ID cards, physical keys etc being used for human identification can be misplaced, robbed, copied, or left at home. Moreover, passwords can be lost, hacked, or detected. Besides, people have to recall a large number of passwords for e-mail accounts, wireless phones, ATMs, computer accounts, web sites and so forth. Conventional entity and knowledge based biometric systems raises security concerns regarding the risk of identifying spoofing attacks[2,3].

As identification and verification are implicit and explicit claim of identity respectively[4]. ECG based biometric system are capable to provide swift, user-friendly, accurate, valid and inexpensive technique for

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identification and verification. Moreover exploiting this technology for identifying people offers some unique advantages i.e. ECG contain inherent information about the liveliness of the subject which conventional biometric systems don't have in[5]. In[6] reveal that every individual has unique ECG features, which can be employed as a biometric attribute. They obtain ECG data via electrocardiogram measuring devices and collected amplitude of ECG signal to compare features.

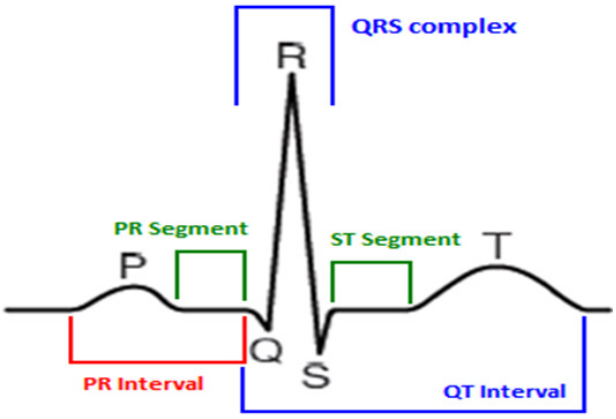

Figure 1. Prototype of an ECG waveform.

Correct and reliable person identification and verification is becoming inevitable and there is a great need of research in the domain of physiological biometrics due to its requirement for the development of fool proof security systems. Therefore this technology is considered as the bottom line of highly protected recognition tools.

In this research we try to exploit the fiducial and non-fiducial techniques for human identification and verification in ECG based biometric systems. The remaining part of this paper consists of section 2 that is related to common characteristics of a biometric technique, section 3 which discusses the associated work, section 4 explain and compare the fiducial and non-fiducial techniques, section 5 gives conclusion and references are given at the end.

2. Common Characteristics of Biometric Systems

A common biometric system should have the subsequent properties explained by[7]:

- **Universality:** Every person should posses that biometric trait. Otherwise it should have room for that people in some way who don't posses that biometric property.
- **Exclusivity:** That Biometric should be unique and distinguishable up to some extent across individuals.
- **Permanence:** That biometric trait should be stable and durable for a longtime period and have negligible effect of substantial and mental actions like thinking, reading, sitting, walking, jogging, sleeping, eating, smoking etc.
- **Collectability:** The process of measuring and accessing biometric traits must be convenient and quick and users don't have any hesitation to exercise the system.
- **Performance:** Adopted method should have acceptable performance for concerned application.
- **Acceptability:** Selected biometric have minimum computational cost. Target population must accept the way of collecting data. Must be compatible with culture and norms of society.
- **Circumvention:** This indicates the extent of reliability in order to make it foolproof.

3. Related Work

Process of feature extraction in ECG based biometrics can be separated into two main classes i.e. fiducial and non-fiducial detection approaches. Non-fiducial detection approach can be further divided into two main headings i.e. transform domain approaches and model based approaches[8,9]. While fiducial based approach is classified into just one category of time interval and amplitude based approach Figure 2. However detection of R-peak is desirable in some transform domain approaches[10]. Temporal or time domain features can be extracted by using Entropy, mean, harmonic mean, range, Inter quartile range, mean absolute deviation, moment, skewness, kurtosis, percentile and gradient[11]. On the other hand Fourier transform, Wavelet transform, wavelet energy, pseudo spectrum, fast approximate entropy[12] are the techniques to extract the non temporal or frequency domain features. Moreover the concept of hybrid biometrics is also given in literature[13].

Reference[14] propose a non-fiducial method of matching reduced binary patterns using MIT-BIH arrhythmia and normal sinus rhythm databases which neither demands complex information of waveform nor de-noising nor advance pre-processing. It recognized noise contained by

ECG signal as attribute to improve the classification rate. The hit rates for distinct databases i.e. with and without significant arrhythmias are correspondingly 95.791% and 90.196%.

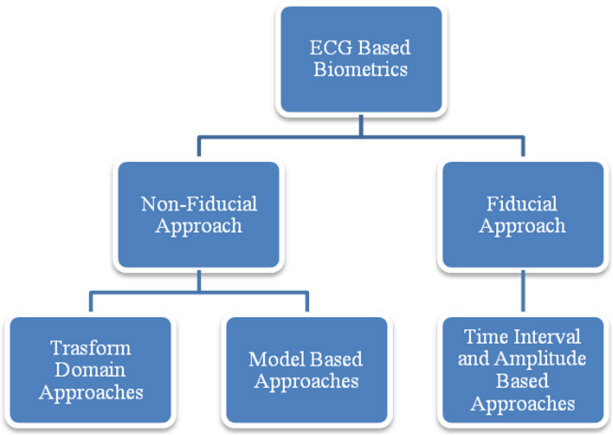

Figure 2. Techniques of feature extraction in ECG based biometrics.

Reference[15] used 16 participants both male and female between 20 to 40 years old and extracted 24 features from ECG record. Sequential forward selection algorithm is used for feature reduction. 100% classification was achieved using 9 features out of 24 but for a small dataset having only 16 participants. Feature reduction process has significant importance to remove the features which are not relevant to the classifier both in fiducial and non-fiducial techniques. The selection of necessary and relevant features can reduce 50% of running and testing time of a classifier[16].

Again in [17] fiducial based techniques is applied to extract 24 differentiable features from ECG signal of 16 users. Feature selection technique based on threshold is used to remove the outliers and 9 features are selected for training and testing. Output of this system recognizes all alternative users except five false detections due to setting fix threshold for each individual. However dataset was again very small consisting of only 16 subjects.

4. Comparison of Fiducial verses Non-Fiducial Techniques

Fiducial feature extraction[12,18] and non-fiducial feature extraction techniques[19,20] are two different approaches used in the literature to deduce useful information from the ECG signal. Feature extraction process use fiducial techniques that refer to the fix standard of reference in an ECG called biomarkers i.e. three composite waves P, QRS and T for every heartbeat[8]. The fiducial based approach needs computation of amplitude and temporal distances between fiducial points that signify the local maxima and minima, prominent heights, depression between peaks, onsets and offsets of a single heart waveform. Therefore, a fiducial feature completely depends on the precise detection of points of interest. Then again, non-fiducial techniques dig out discriminative clues from the ECG waveform without finding intermediate features[9]. In this case, an overall model from multiple heartbeat signals may be used as a characteristic.

Most of the research in the field of ECG based biometrics is carried out on obtaining fiducial based features[8] for developing identification and verification systems. But this technique has number of drawbacks listed below;

- Finding exact location of fiducial points is not an easy task for researchers as it directly affects the accuracy of fiducial features[8].
- Many fiducial detection algorithms have computational overhead as well as time constraints[14].
- While recording, a considerable amount of noise added to the ECG signal due to displacement of electrodes caused by breathing and movement of the subject.
- Each electrode also has built in noise present in it. And even after filtering, the records are not noise free and some noise is still present[8].
- Consequently, the inaccuracy of detection increases due to the onset and the offsets of the composite waves P, QRS and T[8].
- There is no generally recognized rule available in the literature for defining significant boundaries or biomarkers of the wave which leads to misclassification, even if we have accurate ECG records[20].

Considering all these aspects, researchers are confident to make use of non-fiducial based approaches and improve domino effect in which no reference detection is needed at all[21-23]. It has been found that a morphological characteristic-based biometric routine is more protected against spoofing attacks as compared to fiducial point based technique[24]. Sometimes hybrid of

Table 1. Comparison of different techniques in ECG based biometrics

Author	Features	Methodology	Subjects	Accuracy
Biel [HYPERLINK\l "LBi01" 6]	Fiducial	PCA	20	100%
Shen 12]	Fiducial	Template Matching + DBNN	20	100%
Israel [HYPERLINK\l "SIs05" 11]	Fiducial	LDA	29	98%
Gahi 15]	Fiducial	Template Matching	16	100%
Janani, David [HYPERLINK\l "SJa09" 26]	Both	KNN + Bayesian	17	88%
M.M.T Abdelraheem 27]	Both	Fourier Descriptor Coefficients + VCG	22	99.45%
Zeng [HYPERLINK\l "FZe12" 14]	Non Fiducial	Reduced Binary Pattern	48	95.79%
Chiu 19]	Non Fiducial	Wavelet Distance + LDA	35	100%
Chan [HYPERLINK\l "ADC08" 20]	Non Fiducial	Wavelet DM	50	95%

fiducial and non-fiducial approaches is also applied in literature which requires only the detection of R peak as location for distribution of ECG signal[25-27].

Table 1 shows the comparison of fiducial and non-fiducial based techniques used by different researchers in term of methodology, number of subjects and identification accuracy. According to the table accuracy is high, touching hundred when features extracted by applying fiducial methods, but in these cases data set consists of small number of subjects. This is one of the main pitfalls of the fiducial based technique. For larger data sets, non-fiducial methods proved more accurate results.

5. Conclusion

In this research a comprehensive literature review of ECG based biometric systems has been made. In the context two fundamental methods i.e. fiducial and non-fiducial techniques of feature extraction has been studied for people identification and verification. Very high efficiency has been obtained by using fiducial techniques of feature extraction with small data sets. On the contrary non-fiducial techniques do not depend severely on the finding of fiducial points contained by the ECG signal and gives comparatively high efficiency for large population. We can conclude that there is a need to exploit non-fiducial techniques for feature extraction within ECG signal to develop high performance biometric system.

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