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ECG Based Human Authentication: A Review

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Abstract: *With the current technological advancements in the field of medical diagnosis, measurements and increasing health diseases, it has become essential to devise a system for monitoring the patients remotely by using latest technologies. Various researchers have been working in the area to provide an ease in monitoring of high risk patients.This paper presents a review report prepared after an exhaustive literature survey in the area of patient authentication through ECG. It discusses the comparative analysis on the basis of various diseases, physiological and other sensors used, Signal processing techniques, Information management, communication technologies used to remotely monitor the patients. Finally it illustrates the scope of future research work.*

Keywords: *Electrogram(ECG),Biometrics,Identification,Methodology*

1. Introduction

The idea of this research proposal is patient authentication which is a necessary security requirement in remote health monitoring scenarios. The monitoring system needs to make sure that the data is coming from the right person before any medical or financial decisions are made based on data. Credential based authentication methods (eg; passwords ,certificates)are not well suited for remote healthcare as patients could handover credentials to someone else .Furthermore one time authentication using credentials or trait based biometrics (eg; face, fingerprints)do not cover the entire monitoring period and may lead to unauthorized post-authentication use. Recent studies have shown that some human body parameters exhibit unique patterns that can be used to discriminate individuals. This type of Authentication is most useful when patient is in critical situation (like heart attack etc) and he or she is not able to provide required credentials or trait based biometrics. In the case of biometrics that requires active participation by the subject, this can be greatly frustrating. In this proposal, a ECG-based biometric scheme is appropriate that presents many desirable features. The human ECG, an electrical signal that is associated with the electrical activity of heart offers several benefits as a biometric: it is universal, continuous and difficult to falsify. Remote health monitoring of high risk patients and the patients with chronic disorders has become of vital importance as the data can remotely be analyzed by the experts in the field and proper care be taken from time to time. Further high cost of hospital treatment, the necessity of home care assistance, less availability of expert doctors & high quality instruments also demand auto patient monitoring. The analysis on the basis of some selected research papers is presented here. The Sensate Liner[1], integrating sensing elements, processors and transmitters and embedded in form fitting garments had been developed to monitor combat casualties. Wearable computer as a multi-parametric monitor of physiological signals has been developed to measure ECG, Oximetry and Blood pulse[4]. It could send real time signals to remote station over computer network. An Ambulatory blood pressure monitor MediWatch was developed in 2001.[5] A wrist worn medical monitoring computer ‘AMON’ has been designed during 2002 which could monitor and analyze the physiological parameters[7] . A novel micro-electronic pill was developed for situ studies of gastro-intestinal tract combining microsensors and integration circuits with system level integration technology[11] . A micro impulse radar concept has been presented to detect heart rate without touching the patient [12]. Wireless sensor networks and the protocols has been developed health monitoring[14],[16] . The researchers have worked upon various platforms and the technologies to be used in remote health monitoring.

General architecture of Remote Health Monitoring (in Figure 1)

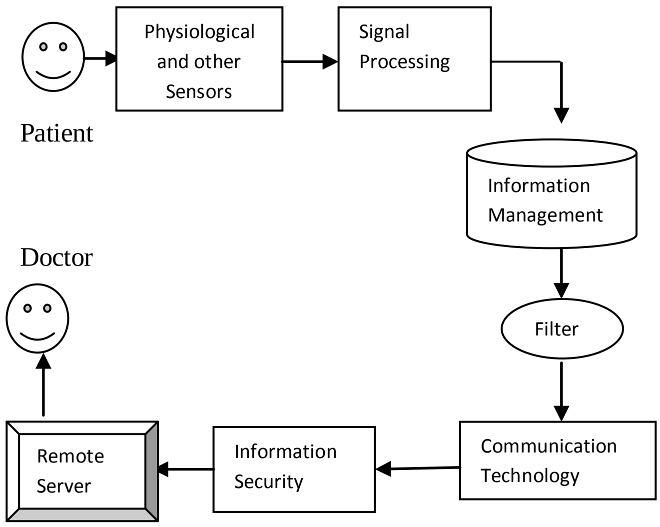

Figure 1. *Architecture of remote health monitoring*

1.1 Physiological and Other Sensors

Today many sensors have been developed which consumes less power, reduced size and low costs. This has facilitated the researchers to develop the health monitoring systems which can be used at home by embedding these sensors in the patient's wearables [10]. From some select literature review, it appears that most of the physiological sensors like ECG, Respiratory, Blood Pressure, Respiration Rate, Oxygen saturation, Temperature, Body impedance, and Heart Rate have been used individually or in combination to remotely monitor the health of patients. These sensors could be embedded in wearable garments, jewelry, clothing or beds and the furniture for continual physiological measurements as well as environmental measurements to identify a wearer's physiological conditions. Pressure sensor, galvanic skin response sensors, flex sensors, piezo-electric film & temperature sensors, EIP, and PPG [2] have also been used.

1.2 Data Processing Technologies

Data acquisition from the sensors and signal processing has also been advanced from time to time. The most common components of this unit are signal amplification, noise removal and its conversion from analog to digital form. The sensory signals so transformed into digital form are carried over as information over the media. The analog signals after amplification and noise removal can directly be processed to extract important features and be processed further to diagnose the health condition of high risk patients who needs continuous attention. Digital signal processing makes it possible to implement these aspects using hardware/software tools. The advancement in embedded technologies such as hardware description languages, design tools to simulate and synthesize, concept of hardware-software co-design with the availability of low power tiny processors fetches numerous solutions to this process. Statistical Probability theory [5], Neural Networks & Fuzzy logic [2], [5] and the Expert System [32] concepts have been used in the literature.

1.3 Information Management Technology

The digital signal information, the features extracted and the diagnosis relevant measures need to be properly maintained at some local server or temporary storage devices, before its remote transmission. Data fusion from multiple sensors, decision making & functional assessment components include PC, mobile devices, and PDAs. A sever array contains data base server DB2 [9], [6], web servers, application sever & load balancing server.

1.4 Communication Technologies:-

Remote data transmission through wired or wireless media includes various technologies Bluetooth, Infrared, UWB (ultra wide band) & RF Communication [16], GSM & GPRS [20], CDMA, Wi-Fi / Wi-Max etc.

1.5 Security Related Technologies

To secure the confidential information of patient of user from viruses & denial of service attacks broken severs and firewalls introduced between client & remote server.

2. ECG BASICS

In remote health monitoring ECG (electrocardiogram) is an essential physiological parameter which is needed to monitor in almost all critical diseases related to heart. Authentication of patients, during monitoring should not need any additional parameter to be recorded. The human ECG, an electrical signal that is associated with the electrical activity of heart offers several benefits as a biometric: it is universal, continuous and difficult to falsify. The ECG signal from different individuals confirm to a fundamental morphology but also exhibits several personalized traits, such as relative timings of the various peaks, beat geometry, and responses to stress and activity. With this concept in mind, the primary focus of literature review has been ECG.

The human electrocardiogram reflects the specific pattern of electrical activity of the heart throughout the cardiac cycle, and can be seen as changes in potential difference. The ECG is affected by a number of physiological factors including age, body weight, and cardiac abnormalities. A typical beat in an electrocardiogram consists of-

1. A low amplitude P-wave, representing arterial depolarization.

2. The QRS complex of much higher amplitude than the P-wave, representing ventricular depolarization

3. A T-wave of smaller amplitude and larger duration than the QRS complex, representing ventricular re-polarization

2.1 ECG

Electrocardiogram (ECG) is a method to measure and record different electrical potentials of the heart. The ECG may roughly be divided into the phases of depolarization and repolarization of the muscles fiber making up the heart. The depolarization correspond to the P-Wave (atrial depolarization) and QRS wave (ventricles depolarization).The repolarization correspond to the T-wave.The ECG is measured by placing electrodes on selected spots on human body surface.

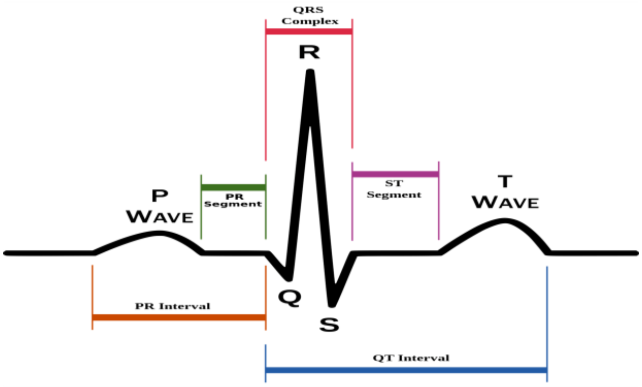

Figure 2. *Basic shape of an ECG*

2.2 (ECG Data Collection

Some of the authors used self collected data and some used MIT-BIH Arrhythmia database. The MIT-BIH arrhythmias database (MITDB) is typically used as a benchmark for the arrhythmia detection and classification .

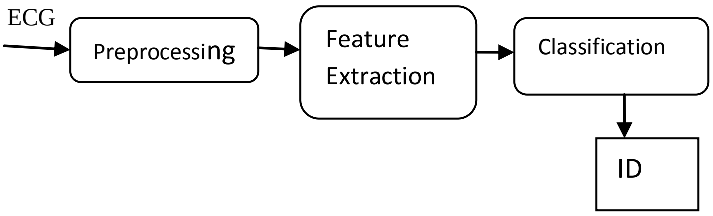

Figure 3. *Block diagram of proposed System*

2.3 Preprocessing

The collected ECG data usually contain noise ,which include low frequency components that cause baseline wander and high frequency components such as power line interfaces. Generally the presence of noise will corrupt the signal, and make the feature extraction and classification less accurate. To minimize the negative effects of noise a denoising procedure is important, for example Wang uses[23] butter worth bandpass filter to perform noise reduction. A thresholding method is then applied to remove the outliers that are not appropriate for training and classification.

2.4 Feature Extraction

Statistical features like dower matrix, correlation coefficient, covariance matrix etc ,wavelet features like ICA, Fourier transform, Discrete cosine transform (DCT) etc techniques are used to extract the features of ECG.

2.5 Classification

Various classification techniques like Support vector machine(SVM),K-nearest neighbor, Baysian network, neural network ,soft independent modeling of class analogy(SIMCA),Principle component analysis(PCA)are used in different papers.

3. RELATED WORK

Although extensive studies have been conducted for ECG based clinical applications, the research for ECG-based bio-metric recognition is still in its infant stage. In this section, we provide a review of the related works. Biel et al. [2] are among the earliest effort that demonstrates the possibility of utilizing ECG for human identification purposes. A set of temporal and amplitude features are extracted from a SIEMENS ECG equipment directly. A feature selection algorithm based on simple analysis of correlation matrix is employed to reduce the dimensionality of features. Further selection of feature set is based on experiments. A multivariate analysis-based method is used for classification. The system was tested on a database of 20 per-sons, and 100% identification rate was achieved by using empirically selected features. A major drawback of Biel et al.'s method is the lack of automatic recognition due to the employment of specific equipment for feature extraction. This limits the scope of applications. Irvine et al. [3] introduced a system to utilize heart rate variability (HRV) as a biometric for human identification. Israel et al. [4] subsequently proposed a more extensive set of descriptors to characterize ECG trace. An input ECG signal is first preprocessed by a bandpass filter. The peaks are established by finding the local maximum in a region surrounding each of the P,R,T complexes, and minimum radius curvature is used to find the onset and end of P and T waves. A total number of 15 features, which are time du-ration between detected fiducial points, are extracted from each heartbeat. A Wilks' Lambda method is applied for feature selection and linear discriminant analysis for classification. This system was tested on a database of 29 subjects with 100% human identification rate and around 81% heartbeat recognition rate can be achieved. In a later work, Israel et al.[5] presented a multimodality system that integrate face and ECG signal for biometric identification. Israel et al.'s method provides automatic recognition, but the identification accuracy with respect to heartbeat is low due to the insufficient representation of the feature extraction methods.Shen et al. [6] introduced a two-step scheme for identity verification from one-lead ECG. A template matching method is first used to compute the correlation coefficient for comparison of two QRS complexes. A decision-based neural network (DBNN) approach is then applied to complete the verification from the possible candidates selected with template matching. The inputs to the DBNN are seven temporal and amplitude features extracted from QRS T wave. The experimental results from 20 subjects showed that the correct verification rate was 95% for template matching, 80% for the DBNN, and 100% for combining the two methods. Shen [7] extended the proposed methods in a larger database that contains 168 normal healthy subjects. Template matching and mean square error (MSE) methods were compared for prescreening, and distance classification and DBNN compared for second-level classification. The features employed for the second-level classification are seventeen temporal and amplitude features. The best identification rate for 168 subjects is 95 .3% using template matching and distance classification. In summary, existing works utilize feature vectors that are measured from different parts of the ECG signal for classification. These features are either time duration, or amplitude differences between fiducial points. However, accurate fiducial detection is a difficult task since current fiducial detection machines are built solely for the medical field,where only the approximate locations of fiducial points are required for diagnostic purposes. Even if these detectors are accurate in identifying exact fiducial locations validated by cardiologists, there is no universally acknowledged rule for defining exactly where the wave boundaries lie [14]. In this paper, we first generalize existing works by applying similar analytic features, that is, temporal and amplitude distance attributes. Our experimentation shows that by using analytic features alone, reliable performance cannot be obtained.To improve the identification accuracy, an appearance-based approach which only requires detection of the R peak is introduced, and a hierarchical classification scheme is proposed to integrate the two streams of features. Finally, we present a method that does not need any fiducial detection.This method is based on classification of coefficients from the discrete cosine transform (DCT) of the autocorrelation (AC) sequence of windowed ECG data segments. As such,it is insensitive to heart rate variations, simple and computationally efficient. Computer simulations demonstrate that it is possible to achieve high recognition accuracy without pulse synchronization. M. M. T. Abdelraheem , et al[34] used only the main loop of the VCG for identification. Two different Algorithms are used. In the first one coefficients from specially developed descriptor(the eqal distance descriptor)are used for identification and in the second, selected Fourier descriptor coefficients of the main loop of the VCG are used as biometric data. In both methods feed forward neural networks are used as classifiers giving identification.But the system was not suitable for long term heart beats and with physical activities like running,walking,etc.

Wang et al. [23] were the first to propose an approach that did not entirely rely on fiducial based features by combining a set of analytic features' derived from Fiducial points with 'appearance features' obtained using PCA and LDA(principal component analysis and linear discriminate analysis**)** for feature extraction and data reduction . The accuracy for 13 subjects was 84% using analytic features alone and 96% using LDA with K-NN(K-nearest neighbor). The combination of the types of features was used to achieve 100% accuracy. Janani, et al [28] handle activity induced ECG variation by extracting a set of accelerometer features that characterize different physical activities along with fiducial and non fiducial ECG features. This is the first paper which involves usage of ECG data when the subject is in motion.Bayesian Classification uses the Accelerometer data accurately which improves the performance with High Accuracy Rate: 88%. It used the SHIMMER platform developed by Intel Digital Health Advanced Technology Group. The SHIMMER1 is a compact sensing platform with an integrated 3axis accelerometer. Chan et al.[25] proposed another non-Fiducial feature extraction framework using a set of distance measures including a novel wavelet transform distance . Data was collected from 50 subjects using button electrodes held between the thumb and finger. The wavelet transform distance outperforms other measures with an accuracy of 89% **.**Can Ye et al[30] use a two-lead ECG signals for human identification. Wavelet Transform and Independent Component Analysis are applied to each single lead signal to extract morphological information. The information from two leads is fused by rejecting the heartbeat segments that are inconsistently classified between two leads. This decision-based fusion significantly enhanced the identification accuracy.

The subject identity is finally determined based on the majority voting among multiple consecutive consistently classified heartbeats. The methodology has been validated over three public ECG databases and substantially high rank-1 IDAs (as high as 99.6%) are achieved in the short-term as well as in the long-term and with or wiyhout the presence of arrhythmia. The result demonstrates the great potential of ECG signals and the proposed method in the biometrics system.Wang et al. [23] were the first to propose an approach that did not entirely rely on fiducial based features by combining a set of analytic features' derived from Fiducial points with 'appearance features' obtained using PCA and LDA(principal component analysis and linear discriminate analysis**)** for feature extraction and data reduction . The accuracy for 13 subjects was 84% using analytic features alone and 96% using LDA with K-NN(K-nearest neighbor). The combination of the types of features was used to achieve 100% accuracy.

4. COMPARISON

Table1. *Comparison of methodology*

Reference	Features	Methodology	Subjects	Activity	Accuracy
Biel [3]	Fiducial	PCA	20	No	100%
Shen [8]	Fiducial	Template Matching + DBNN	20	No	100%
Israel [15]	Fiducial	LDA	29	No	98%
Wang[23]	Both	KNN+LDA	13	No	96%

Chiu[26]	Non Fiducial	Waverlet Distance+LDA	35	No	100%
Chan[25]	Non-Fiducial	Wavelet DM	50	No	89%
Janani, David[28]	Both	KNN + Bayesim	17	Yes	88%
Can ye[30]	Both	Wavelet Transform+ ICA	47	No	99.6%
Fahim,Khalil[31]		Both		Review Paper	
R.Martin Arthur[33]	Both	PCA	-	No	-
M.M.T Abdelraheem[34]	Both	Fourier Descriptor Cofficients+VCG	22	No	99.45%

Table2. *Comparision of critical parameters-*

Reference	**Support Long term ECG**	**Support increased Heart rate**	**Support Different Stress level**
Biel [3]	No	No	No
Israel [15]	Yes	No	Yes
Wang[23]	No	No	No
Chiu[26]	No	No	No
Janani, David[28]	Yes	No	No

5. PROPOSED SYSTEM

Proposed system should be stable for long time intervals with physical activities like Sitting, walking, jogging, running, resting, drinking, smoking etc. Research has also been carried out on various platforms, communication technologies and protocols, expert system development, security and services.

6. CONCLUSION

An exhaustive literature review on remote health monitoring by using multi parametric physiological signals, internetworking technologies, development platforms and the technologies, sensory architecture, management of data, data processing and communication technologies and the security threats, it can be concluded that although there has been a significant research in the field of remote health monitoring, there is a scope of further research with respect to an artful design of architecture for remote health monitoring system with adaptive wireless sensor nodes embedded in either in bodywear or in the environment around the patient.

7. FAILURE AND NEW CHALLENGES

- The authentication in remote health monitoring system plays vital role(authentication using credentials or trait based biometrics (eg; face, fingerprints)do not cover the entire monitoring period and may lead to unauthorized post-authentication use), while still there are certain issues to consider upon.
- Most of the research has not considered patients physical activity or wide range of heart beats while recording ECG and hence that is an area of concern.
- Most of the research uses R waves in ECG to analyze by sacrificing P and T, however, their inclusion may lead to better diagnosis
- There is also a scope in design of security algorithms.

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