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PRIVACY PROTECTION IN ECG STEGANOGRAPHY BASED ON TELEMEDICINE APPLICATION

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Abstract—This paper presents a person identification mechanism mistreatment electrocardiogram (ECG) signals with abnormal internal organ conditions in network environments. a complete of 164 subjects were used in this paper mistreatment three totally different informations containing various irregular heart states from MIT-BIH arrhythmia database (MITDB), MIT-BIH supraventricular heart disease info (SVDB), and Charles Sturt polygenic disorder complication screening initiative (DiSciRi) information. We have a tendency to projected a straightforward however effective biometric sample extraction technique for electrocardiogram samples with abnormal internal organ conditions to enhance the person identification method. These sample points were then applied to four classifiers to verify the strength of identification. Varied numbers of enrollment and recognition QRS complexes were wont to validate the soundness of the projected methodology. Our experimentation results show that the biometric technique outperforms existing ways lacking the power to efficiently extract features for biometric matching. This can be evident by getting high accuracy results of ninety six.7% for MITDB, 96.4% for SVDB, and 99.3% for DiSciRi. Moreover, high sensitivity, specificity, positive prophetic price, and Youden Index's values additional verifies the reliableness of the projected methodology. This system conjointly suggests the likelihood of up the classification performance mistreatment electrocardiogram recordings with low oftenness and raised variety of electrocardiogram samples.

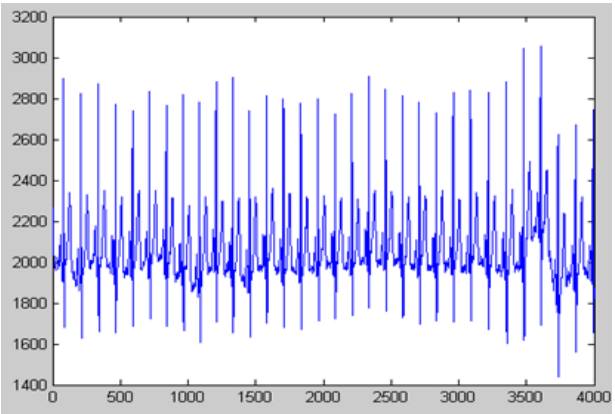
Index Terms—Abnormal cardiac condition, Bayes network, biomedical signal processing, biometric, electrocardiography, KNN, multilayer perceptron (MLP), normalization, pattern classification, radial basis function (RBF).

I. INTRODUCTION

In The past decade, the electrocardiogram (ECG) biometric has established itself as a substantial body of knowledge which primarily focuses on improving the recognition performance. Adhering to the concept of pattern recognition, improvising and enhancing previous and existing methods have solved ambiguities in the process of subject recognition. As a result, varying preprocessing procedures, feature extraction techniques and subject recognition methods have been proposed such as previous findings in [1]–[14] which includes our research works in [6], [7], and [10]–[14]. Based on these studies, most of the participants consist of normal and healthy subjects. The terminology normal and healthy refers to subjects with normal sinus rhythm (heart beat) without significant cardiac abnormalities. However, little has been said about the reliability of ECG biometric in irregular heart conditions. Even though, there have been initial investigations on this matter such as related works in [12], [13], and [15]–[17] but the area is still under-research and needs a lot more justification to prove the robustness of ECG biometric in abnormal cardiac conditions. Furthermore, some research focuses on certain kinds of heart diseases. Therefore, we propose a simple yet effective biometric matching technique that is able to identify individuals in different pathological conditions where we expand the possibility of performing biometric in varying heart states. Thus, if we are able to identify subjects regardless of the heart status, it would become an essential tool to identify a person especially in scenarios such as remote monitoring systems where patients may exhibit abnormalities.

A. Motivation

Possible scenarios and applications of ECG biometric in a multiuser network are illustrated in Fig. 1. According to this figure, ECG signals are first collected using acquisition devices from different sources such as handheld units, capacitive ECG garments or even contactless ECG sensors on driver's seats in a variety of remote locations such as aged care centers, patients at home or away, soldiers in battle fields or even drivers in automobile. ECG data are then sent to a mobile communication device via near field communication (NFC), Bluetooth, WiFi, etc. From the mobile device, data packets are sent electronically via public network to servers which connect to related organizations such as hospitals, military and security companies for assessments. However, before authorized packets are released, servers monitor and analyze ECG packets in order to prevent net- work attacks. In this scenario, the receiving end (server) will be overwhelmed with large amounts of ECG data coming from multiple source nodes. If security procedures are not properly dealt with, the system would be exposed to security attacks which could potentially overload the server or sensor nodes with undesirable information. The attacks could also attempt to disrupt service to a specific system and prevent the host from communicating on the network. Attackers against server sys- tem which remotely monitor subjects can be very application specific by spoofing valid IP addresses of authorized subjects. These attacks are meant to disrupt the monitoring service by continuously sending ECG data of unregistered subjects [18]–[21]. Moreover, Health Insurance Portability and Accountability Act (HIPAA) 1996 [22], European Union Directive 2002/58/EC [23] and Law of the People Republic of China on Medical Practitioners [24] recommends security procedures for electronic protected health information to be securely performed. Related studies such as [25]–[27] have previously proposed ECG biometric for network security, however, in [25] and [26] these studies only involved healthy subjects while testing the robustness of their proposed approaches. Moreover, research work in [27] concludes that cardiac abnormalities causes inter pulse interval (IPI) to vary and thus decreasing the passing rates. Therefore, the main factor that motivates us to per- form this paper is to evaluate the classification performance of ECG biometric within abnormal cardiac conditions in network environments to prevent security attacks.



B. Contributions

This paper considers two aspects neglected in existing works while performing ECG biometric with cardiac abnormalities. 1) Extensive studies have been performed across classifiers and among different cardiac abnormalities to verify the robustness of the proposed method which are not covered in the existing works [12], [13], [15]–[17]. 2) proposed an innovative biometric sample extraction technique that is simple and accurate which consist of QRS sample normalization and convolution methods. Therefore, the proposed study is relevant and significant as it covers other aspects of performing ECG biometric with abnormal cardiac conditions which could be enhanced for a more reliable and effective remote monitoring system. Based on our experimentation, the proposed biometric sample extraction

technique outperforms the existing methods lacking ability to efficiently extract biometric features. This is supported by obtaining high accuracy results of 96.7% for MITDB, 96.4% for SVDB, and 99.3% for DiSciRi. Moreover, as to verify the reliability of the proposed technique, high sensitivity, specificity, positive predictive value and Youden index's values are computed. This technique also suggests the possibility of improving the classification performance using ECG recordings with low sampling frequency and increased number of QRS complexes.

Initial research work has been conducted to investigate person identification in abnormal cardiac conditions using ECG signal in these recent years such as in [15]–[17]. Agrafioti and Hatzinakos [15] using the nearest neighbor (NN) classifier obtained a classification rate of 96.2% when applying autocorrelation/discrete cosine transform (AC/DCT) method to 79 subjects with atrial premature contraction (APC) and premature ventricular contraction (PVC) from three different public databases. These databases are MIT-BIH normal sinus rhythm database (NSRDB), MIT-BIH arrhythmia database (MITDB), and PTB diagnostic ECG database (PTBDB). Implemented longitudinal and cross section investigation for 23 subjects with peritoneal dialysis from the Tsu Nzi General Hospital Taiwan for a period of two years. During these two years, a decrease of subject recognition from 98.5% to 87.7% was computed.

In summary, these studies investigated similar issues pertaining to ECG biometric in irregular cardiac conditions. However, there are still rooms for improvement and enhancements based on these related works. The drawback of the research work in [15] is the reliance on NSRDB and PTBDB which contains subjects who do not experience significant arrhythmias and thus making the outcome not reliable. Furthermore, the study concentrated only on APC and PVC cases. Thus, in this paper, we intend to extend cardiac abnormalities to other types of irregular heart conditions such as supra ventricular arrhythmia, atrial fibrillation and cardiac autonomic neuropathy for subject recognition. Studies in [16] achieved a good recognition rate of 98.5% but what is surprising is that the accuracy rate for a period of two years worsening to 87.7%. Even though in our work we do not intend to analyze the 11% decrease, however, this paper showed that person identification is still possible on subject with abnormalities. The authors also suggested recalibrating the recognition system after a few years but the recalibration process and its extent is quite unclear.

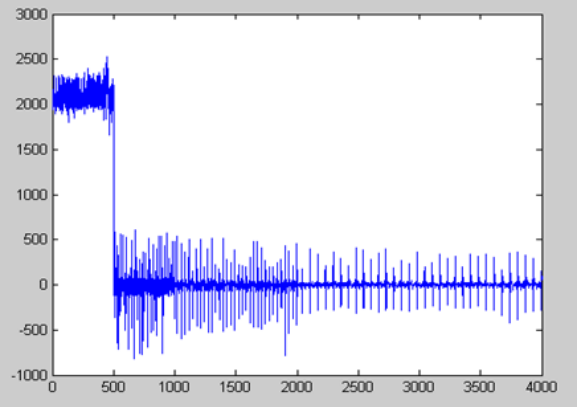
II. SYSTEM AND METHOD

An ECG biometric system implements the pattern recognition procedure by comparing enrollment and recognition ECG datasets. Both datasets consist of ECG signal from subjects with normal and abnormal cardiac conditions acquired from three public databases. A successful match recognizes a subject's identity as illustrated in Fig. 2. As can be seen in this figure, ECG signals which consist of normal and abnormal segments are divided into training and testing sets. After obtaining these datasets, we perform biometric matching using our proposed biometric sample extraction technique. Once this approach is implemented, we later classify the output using four common induction algorithms for person identification. The proposed ECG biometric process of subject with abnormal cardiac conditions is elaborated further in the next section.

A. Signal Acquisition

Ten seconds of ECG recordings were obtained from each subject acquired from three different databases containing various pathological conditions such as atrial fibrillation, supra ventricular arrhythmia and cardiac autonomic neuropathy. The databases involved are MIT-BIH supra ventricular arrhythmia database (SVDB), MIT-BIH arrhythmia database (MITDB) and Charles Sturt diabetes complication screening initiative (DiSciRi). A total of 164 subjects were used from these repositories, 67

subjects experiencing supra ventricular arrhythmia were taken from SVDB and another set of 46 subjects using modified lead II (MLII) were obtained from MITDB. SVDB and MITDB each have sampling rates of 128 Hz and 360 Hz respectively. These datasets were fetched from Physio Net [28], an online public database with a large collection of physiological signals. The remaining 51 subjects were obtained from DiSciRi that experienced early, definite and severe Cardiac Autonomy Neuropathy (CAN) with sampling rate of 400 Hz. The research procedure was approved by Charles Sturt University Ethics in Human Research Committee (03/164).



B. Biometric Sample Extraction

After the ECG data collection stage, we implement our proposed biometric sample extraction technique which consists of QRS sample selection, data normalization, sample convolution and again data normalization to extract salient features and reduce error discrepancies. 1) QRS Sample Selection: Once ECG datasets have been gathered, the amplitude feature which is an analytical method that depicts the morphological shape is used to obtain QRS complexes. From the original ECG signal, the R wave was chosen as the pivotal point as it is the highest and most prevalent peak in an ECG morphology. The next step is selecting equal sample points from both sides of the identified R wave.

III. CONCLUSION

In this paper, we have demonstrated an efficient and accurate person identification technique in abnormal cardiac conditions using ECG signals for a remote monitoring system. A total of 164 subjects were used in this paper from three different databases (SVDB, MITDB, and DiScRi) containing various abnormal heart conditions. We applied the proposed NCN technique to plain QRS complex to improve the identification process to further enhance and verify the reliability of the ECG biometric matching. Our experimentation results on four commonly used classifiers and varying number of enrollment and recognition datasets outperformed methods without using the proposed NCN approach. The proposed technique suggests that person identification is possible by obtaining high sensitivity, specificity, accuracy, PPV and Youden's Index values. Moreover, the results are higher and comparable with existing methods by obtaining classification accuracy of 99.3% for DiSciRi, 96.7% for MITDB and 96.4% for SVDB. These outcomes also verifies and complements our previous works in [12] and [13]. The results indicate that subjects with abnormal cardiac conditions can be identified and thus making the proposed approach suitable for remote cardiac monitoring applications.

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