A Novel Biometric Identification Framework based on ECG Waveforms using k-mean Clustering Algorithm

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Abstract − Recent advancements in computing and digital signal processing technologies have made automated identification of people based on their biological, physiological, or behavioral traits a feasible approach for access control. The wide variety of available technologies has also increased the number of traits and features that can be collected and used to more accurately identify people. Systems that use biological, physiological, or behavioral trait to grant access to resources are called biometric systems. In this paper, we present a biometric identification system based on the Electrocardiogram (ECG) signal. A novel hardware and software framework is proposed and investigated in this work. The proposed system is based on ECG amplitude features and a K-mean clustering for finding the significant features for the identification. The system is installed using an Arduino microcontroller and a Bluetooth signal transmitter is designed on electronic circuit and used for testing the system. Experimental results show significant success ratio and that the proposed system is reliable and feasible.

Keywords − ECG biometric, K-mean ECG, ECG Andriono, Biometric.

I. INTRODUCTION

Biometrics is a promising field of technology that is based on measuring some physical, biological, or behavioural characteristics of a person in order to establish identification, to perform identity verification, or to recognize a person through [1]. Recent advances in the computing signal processing has allowed biometric systems to uniquely identify humans. Biometric systems can rely on a number of features including fingerprints, voice, face, hand geometry and iris. Traditionally, password and ID cards have been commonly used as defense measures to access information systems. However, password proven to be ineffective in providing security protection .To overcome some of the limitations variable password policies have been introduced. Such policies include the use of longer passwords, making a mix of lower and upper-case letters. Despite these policies, passwords can still be cracked.

Recently, researchers have begun investigating the use of the electrocardiogram (ECG) signal as a biometric trait to identify individuals. The characteristics of the ECG signal can be unique and are difficult to falsify. In addition, ECG data is already available from persons that are connected to an electrocardiogram sensor. The validity of using ECG for biometric recognition is supported by the fact that the physiological differences of the heart in different individuals display certain uniqueness in their ECG waveform [2, 10, 20].

An ECG based biometric recognition system can be applied in a wide variety of applications including medical records management, in addition to government applications. In this paper, we present and efficient identification system based on the ECG waveform. The system extracts amplitude features from an ECG signal which are used to uniquely identify individuals, this can done through portable device. The rest of the paper is organized as follows: section 2 presents related studies in this field. The proposed system is explained in section 3. Section 4 presents the results and discussions. We conclude the work in section 5.

II. Electrocardiogram (ECG) signals

Electrocardiogram (ECG) signals have several properties that can greatly complement the existing, and more established biometric modalities. Some of the most prominent properties are the fact that the signals can be continuously acquired using minimally intrusive setups, are not prone to produce latent patterns, and provide intrinsic liveliness detection, opening new opportunities within the area of biometric systems development. The potential impact of this technique extends to a broad variety of application domains, ranging from the entertainment industry to digital transactions .This paper present a framework for ECG biometrics, with focus on some of the latest developments and future trends in the field, covering multiple aspects of the problem with the aim of a real world deployment. The results so far, further reinforce the feasibility and interest of the method in a multi biometrics approach [3, 19, 20].

The unique properties of ECG signals are particularly interesting in a Multi biometrics approach, either as a security enhancement layer in hard biometrics systems, or as a standalone soft biometrics for low security and low user throughput applications. More importantly, as it can be continuously measured, it enables a new class of applications benefitting from the continuous biometric perspective. Experimental results have been performed, which further reinforce the interest of the ECG based methods both in an identification and authentication approach [4].

This paper has evaluated the feasibility of ECG as a biometric for individual authentication and proposed a method for ECG enabled biometric authentication system. Unlike conventional biometrics that are neither secrets nor robust enough against calcification, ECG is in hearted to an individual which is highly secure and impossible to be

forged .Most importantly, ECG has an inherent real time feature of vitality signs which ensures that an ECG cannot be acquired unless the person is not live or it can't be acquired unless the person to be authenticated is not present at the authentication desk. Therefore, it is robust enough against the falsified credentials to be enrolled in the system. We have shown that ECG has potential to provide an excellent source of supplementary information in a multi biometric system .The fusion of ECG with the face biometric and with the fingerprint biometric has shown a significant improvement in authentication performance of both of the fused systems. In addition, the research concerns of ECG enabled biometric authentication system across wide range of conditions. The laboratory demonstration of the biometric use of ECG has shown great promise, but the fruitful directions for further research include the following:

- The ECG enabled biometric system must perform the authentication task across wide range of conditions over a larger population including the data acquired at larger time intervals.
- It is important to discover that up to what ex-tent an ECG varies under different anxiety levels .An investigation of robustness to the subjects of different.

III. RELATED WORKS

Recently, ECG based identification systems has recived extensive studies. In this section, a review of recent related works is presented.

Authors in [2] proposed system where a set of temporal and amplitude features are extracted from an ECG equipment directly. The simple analysis based on correlation matrix algorithm of a feature selection is adopted to reduce the the features. Further selection of feature set is based on experiments. For the classification stage a multivariate analysis-based method is used. For testing the system, 20 persons are used. The main drawback of [2] is that the features are extracted by specific equipment and the user. A system to utilize heart rate variability (HRV) as a biometric for human identification is introduced in [5].

In another study [6], ECG signal is first preprocessed by a bandpass filter. Then, the peaks are established by finding the local maximum in a region surrounding each of the P,R,T. Fifteen features, which are time duration between detected fiducial points, are extracted from each heartbeat. Authors used A Wilks" Lambda method for feature selection and linear discriminant analysis for classification. A multimodality system that integrate face and ECG signal for biometric identification is proposed in [7].

A two-step scheme for identity verification from one-lead ECG is prsented and discussed in Shen et al. [8]. The correlation coefficient for comparison of two QRS complexes is computed by using a template matching method. A decision-based neural network approach is then applied to complete the verification from the selected candidates. Seven temporal and amplitude features extracted from QRS T wave and inputs to the DBNN.

Shen [9] applied the proposed methods in [8]. Template matching and mean square error (MSE) methods are compared for prescreening, and distance classification. Addationally, DBNN compared for second-level classification. Authors use seventeen temporal and amplitude features for the second-level classification.

We found that the literature are using feature vectors that are measured from different parts of the ECG signal for classification, such as 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 [10].

Authors in [11], applied temporal and amplitude distance attributes features. After that an appearance-based approach which only requires detection of the R peak is tested, and a hierarchical classification scheme is proposed to integrate the two streams of features.

Abdelraheem , et a l [12] used coefficients from specially developed descriptor(the eqal distance descriptor) for identification and the selected Fourier descriptor coefficients. In both methods feed forward neural networks are used as classifiers giving identification.

In another study, Janani, et al [13] proposed an approach that examined using ECG variation by extracting a set of accelerometer features that characterize different physical activities along with fiducial and non fiducial ECG features. Bayesian Classification uses the Accelerometer data. It used the SHIMMER platform developed by Intel Digital Health Advanced Technology Group.

Chan et al. [14] proposed another non-Fiducial feature extraction framework using a set of distance measures including a novel wavelet transform distance. Can Ye et al. in [15] 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. The subject identity is finally determined based on the majority voting among multiple consecutive consistently classified heartbeats. The result demonstrates the great potential of ECG signals and the proposed method in the biometrics system.

Wang et al. [16] propose an approach combining a set of analytic features derived from Fiducial points with appearance features obtained using principal component analysis and linear discriminate analysis for feature extraction and data reduction.

IV. PROPOSED APPROACH: HARDWARE AND SOFTWARE

To capture the ECG signal we used the e-health sensor as a recorder, and we used the Bluetooth technology to connect this hardware with the PC. The Bluetooth module we will use is HC-05 which is so familiar and cheap, Arduino support Software Serial, which allow us to change any Arduino board pin to serial pin, we implement Bluetooth in Arduino Uno, Arduino Duemi lanove, and Arduino Mega 2560.

The proposed system consists from the following electronic items: ECG electrodes which are a hardware interface that is easy for user to interact with, E-health shield, Aurdino Mega, and Aurdino Due as shown in Figure 1.
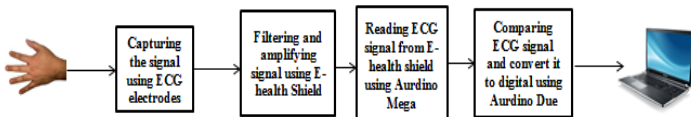

Fig. 1 Electronic items of the system

The ECG based biometric verification is a procedural of verifying the identity of user. It demonstrates by comparison one to one feature stored in database for real person signal and feature currently reading using ECG sensor. Software part use Matlab for test, and C language for identification. The software part was implemented by more than step: the first step record ECG signal from user by ECG hardware recorder, and remove noise from signal using smooth method, then extraction of features to recording verification.

In this work seven amplitude ECG features were used, PR amplitude, QR amplitude, RS amplitude, RT amplitude, PS amplitude and TS amplitude as Figure 2.
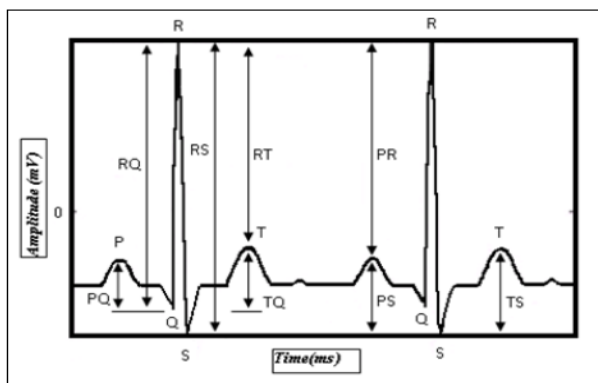

Fig. 2 All amplitude features extracted.

The above features were selected because it has been observed that heartbeat of a person changes from infant to adult person, so the time duration between various peaks and valleys changes. Also amplitude features have minimum changes with age so mostly amplitude features were selected. To feature extraction, in the first we need to find all peaks in ECG signal as show in Figure3.
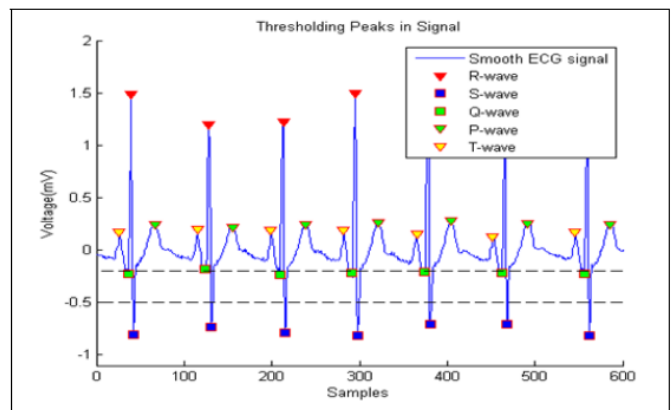

Fig. 3 All peaks in the signal.

The QRS complex detection is an important part of the ECG signal processing system. In this paper the Fuzzy K-Means algorithm for detection of QRS complex in ECG signal, based on the following steps:

1. A raw digital ECG signal is acquired.
2. A raw ECG signal is often contaminated by disturbances such as power line interference and base line wander. There filter hardware circuit to remove it as mentioned before.
3. The gradient at every sampling instant is calculated to enhance the signal in the region of QRS-complex. The various slopes obtained at different sampling instant are divided in clusters. Data centers are randomly assigned to the clusters resulting in clusters that have roughly the same number of data centers.

Then, for each data centers (peaks in ECG signal)
1. Calculate the distance from the data centers to each cluster.
2. If the data centers are closest to its own cluster, leave it where it is. If the data centers are not closest to its own cluster, move it into the closest cluster.
3. Repeat the above step until a complete pass through all the data centers results in no data centers moving from one cluster to another. At this center the clusters are stable and the clustering process ends.

V. Experiments and Results

To evaluate the proposed system we used a database for 10 individuals having 10 samples each and the results a false rejection rate of 0.05 and false acceptance rate 0.06. After take ECG signal from hardware and remove noise by hardware and software filter, then we extract a set of temporal and amplitude features from ECG. The extracted features from the ECG signal were compared one by one with the features of the real person already stored in database. If any specific feature and its corresponding feature stored in the database lies within autocorrelation function, then it was assumed that the two features matched with each other. We tested all seven features for matching. The decision was taken for user, and we considers real one if a minimum 5 out of 7 features of the

subject were matched, access was then provided to the application, otherwise access was denied.

The amplitude feature gave a good percentage and correct result than other feature like angle feature, interval feature and R-R interval , amplitude feature different from person to another , and it doesn't change during person life .but other feature change if person move and sickness. The ECG signal was measured from the user's hand, see Figure 4. The proposed system shows a success rate equals 81%
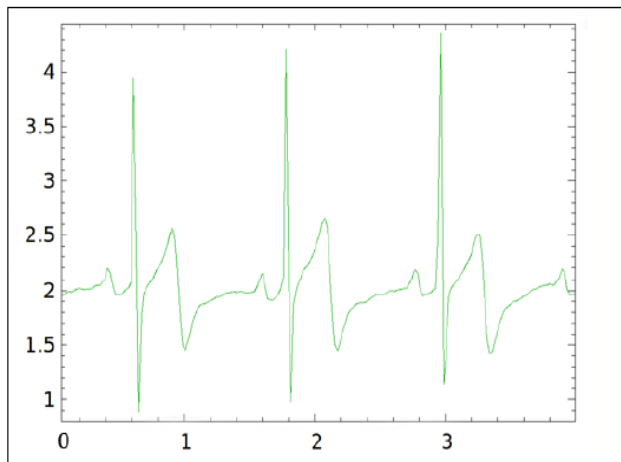

Fig. 4 Output ECG signal from user's hand.

VI. CONCLUSION

Recent advances in biometric field take into the consideration the ECG signals that overcome limitations of traditional biometric authentication like iris, fingerprint.

In this work, a new ECG –based biometric identification system. The hardware and software parts of the system were built and tested. The proposed system is measured amplitude features and k-mean clustering is adopted for the verifying the person.

A significant results achieved in this study in identify one person from another when we used Arduino Microcontroller and the amplitude feature that is unique for each person.

VII. REFERENCES

[1] M. Uddin , S. Sharmin , A.H. Ahmed and E. Hasan , S. Hossain and Muniruzzaman, "A Survey of Biometrics Security System," IJCSNS International Journal of Computer Science and Network Security, vol.11, October 2011.

[2] S. K. Singla1 and A. Sharma, "ECG as biometric in the automated world," International Journal of Computer Science and Communication, vol. 1, pp. 281-283, 2010.

[3] A. karam, "telemedicine systemsing GSM and winetworks." Palestine polytechnic university, 2011.

[4] T. Audesirk and Audesirk, "Gerald,biology,life in earth," Prentice-Hall,1991.

[5] M. Fereniec , M. Kania1 , G. Stix , T.Mroczka and R. Maniewski, " Relation between Depolarization and Repolarization Phases in Body Surface QRST Integral Map", Computers in Cardiology conference, 2007.

[6] L. Sornmo and P. Laguna, "Bioelectrical signal processing in cardia cand neurological applications", Academic Press, June , 2005.

[7] D. H. Wang, F. Agraoti and K. N. Plataniotis, "Analysis of human electrocardiogram for biometric recognition," Corporation EURASIP Journal on Advances in Signal Processing, vol. 10, p. 11, 2008.

[8] T. Shen, W. Tompkins, Y. Hu, "One-lead QRS for identity verification." In Proc. of the Second Joint EMBS/BMES Conference. 2002.

[9] J. Wiley, "Engineering contributions to biophysical electrocardiography," IEEE Press, p. 248, 1982.

[10] Y. Can, C. Miguel, and B. Vijaya, ,"Investigation of human identification using two lead electrogram signals" , Proceedings of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies ,IEEE, Volume 50,2010

[11] Y. Wang, F. Agrafioti, D. Hatzinakos, and K. N. Plataniotis, "Analysis of human electrocardiogram for biometric recognition", EURASIP Journal on Advances in Signal Processing,2008

[12] A. Martis, U. Acharya and C. Chakraborty, "Applicationof higher order cumulants to ecg signals for the cardiac health diagnosis," 33rd Annual International Conference of the IEEE Engineeringin Medicine and Biology Society, 2011.

[13] Y. Wang, F. Agrafioti, D. Hatzinakos, and K. Plataniotis, "Analysis of Human Electrocardiogram for Biometric Recognition," EURASIP Journal on Advances in Signal Processing, 2008.

[14] M. Abdelraheem, H. Selim, T. Abdelhamid," Human Identification Using the Main Loop of the Vectorcardiogram"; American Journal of Signal Processing 2012.

[15] S. Janani, S. Minho, C. Tanzeem, K. David," Activity-aware ECG-based patient authentication for remote health monitoring", International Conference on Mobile Systems,ACM,2009.

[16] D. Chan, M. Hamdy, A. Badre, and V. Badee, "Wavelet distance measure for person identification using electrocardiograms", Transactions on Instrumentation and Measurement, IEEE, Vol. 57,2008.

[17] S. Pal, S. and M. Mitra, "ECG based biometric authentication-a novel data modelling approach", Image Information Processing (ICIIP), IEEE, 2011.

[18] R. D. Labati, V. Piuri, R. Sassi, F. Scotti and G. Sforza, "Adaptive ECG Biometric Recognition: a Study on Re-Enrollment Methods for QRS Signals", Computational Intelligence in Biometrics and Identity Management (CIBIM), IEEE , 2014.

[19] J.B. Fernando, K., Morikawa, " Improvement of human identification accuracy by wavelet of peak-aligned ECG", Security and Behavior Analysis (ISBA), IEEE, 2015.

[20] A. Fratini, M. Sansone, P. Bifulco, and M. Cesarelli "Individual identification via electrocardiogram analysis", Biomed Eng Online, 14: 78, 2015.