Human Authentication Based on ECG imaging

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Abstract:- Human Authentication is one of the most important areas in modern day security system. The authentication can be based on two parameters: 1] Based on what one knows or 2] Based on what one possesses. In this paper, a biometric trait – ECG is used as for the authentication. The ECG image is morphologically processed and then Radon Transform is applied on the preprocessed ECG image to get a Radon image. This Radon image consists of projections for \( \theta \) varying from \( 0^\circ \) to \( 180^\circ \). The feature vector from the Radon image is being computed by the Pair-wise distance. This feature vector is being stored in the database and accessed when an authorized check is needed. The classifier designed brings in the comparison between the feature vectors at different time intervals irrespective of the individual's identity. The overall accuracy of the system is found to be ideally 99.9999%.

Keywords: ECG, Radon Transform, Morphological operation, Pair-wise distance, Feature vector.

I. INTRODUCTION

The present day situation is in a state where the identification or the authentication of a person’s identity is at its critical heights. Unlike using what one knows can be of feeble security at times, Biometrics can be employed. Biometric technologies developed worldwide involve one of the human identification characteristic: Anatomical or Behavioral. Under high security issues, multiple biometrics can be clubbed in a single system. Study relates that physiological characteristics are far ahead of the behavioral traits interms of accuracy, uniqueness, and reliability aspects.

Anatomical traits such as fingerprints or palm scanning or face identification can be forged or falsely created or at the worst scenario can be prone to damage, which affect the health of the security algorithm in the system. To achieve a greater accuracy of almost 100% , researchers and scholars have empowered the idea of using ECG as a biometric trait, for stronger authentication.

The Electrocardiograph is a recording of the heartbeat using skin electrodes with respect to time. Etymology of ECG is derived as Electro- because its related to the electrical activity of the heart & cardio- related to heart and graph- “to write”. ECG of a person is very unique and characterized with the size, position and anatomy of the heart, chest configuration and various other factors. Biel et al. showed that it is possible to identify individuals based on an ECG signal. The initial work on heartbeat biometric recognition used a standard 12-lead electrocardiogram for recording the data.

ECG of a person can be collected with the help of hand-held devices – palm scanners like some advanced Mobile App wherein a Smartphone or a tablet can be used to instantly get the ECG. The ECG of a person can be a very powerful biometric trait which can be used in applications like ATM’s, debit card or credit card services , Bill Payment option can also be embossed.

II. BACKGROUND WORK

Research has showed that an ECG is very unique to every person and faking it really is an impossible task. Until recent years, researchers and scholars were keenly working on the identification of an individual based on the ECG biometric, to quote, the first systematic electrical approach towards the heart was in 1911 by Augustus Waller, in St. Mary’s Hospital in Paddington, London. He traced the heartbeat extracted from his electrocardiograph and tried to apply it for his clinical purpose.

Then the view changed and the revolution began. Willem Eithoven in Leiden, invented a device which had capillary galvanometer, a sensitive device for the electrocardiography. He also tried to name the various deflections with the English alphabets such as P, Q, R, S, and T in the graph obtained from the Electrocardiogram.

Much earlier to this work, Biel et al. had shown that the individual identification is possible based on ECG signals. He had used a 12-lead electrocardiogram for recording the electrical activity of the heart. He even tried to bring out the distinctive features like P-wave duration , onset value etc.

Gradually the researchers came up with the advanced and promising techniques like Soft Independent Modeling of Class Analogy – for classifying individuals and Decision Based
Neural Network (DBNN) and template matching system by Shen et al.

III. ECG BASED BIOMETRIC SYSTEM

A. Architecture and modeling of the ECG Biometric system

The ECG biometric system when deployed in an organization, the first step involves the collection of the ECG data samples in the required image format. Then there is processing of the ECG image accordingly.

In the processing, the ECG image is converted to a gray-scale image and then morphological operation such as dilation and erosion are been applied to finely define the edges of the ECG image. Then the processed ECG image is subjected to Radon transform to obtain a matrix and on which the Euclidean pair-wise distance method is being applied to extract the feature vector.

For feature matching purpose, we design a distance classifier with a governing rule - the feature vector of each ECG entry stored in the system’s database is calculated and then compared the same with that of the claimed person in a looping process. This computed comparative difference in the feature vector, when results in zero is noted and then by declaring as a perfect match found for that individual and the system authenticates and grants the access to the system.

If the difference is not as expected then the system clearly rejects the user’s access into the system.

The architectural diagram of the system is as shown in Fig 1.

B. Algorithm for the ECG Biometric system

The authentication process involves a series of steps as listed hereunder.

1. The person who undergoes the authentication process should first enter his ID and his ECG is captured.
2. The captured ECG signals are plotted as a graph and it is converted to an image.
3. Now, the ECG image will undergo pre-processing to remove the possible noise and to increase the intensity.
4. Radon transform is applied on pre-processed ECG image to get a Radon image. Then pairwise distance is calculated for this image to get a feature vector.
5. The distance classifier takes the necessary and appropriate decision between the feature vector calculated from that of the ECG image database with the newly computed feature vector of the claimed individual.
6. Based on the result of the distance classifier, the decision is taken on whether the claimed person is authenticated or should be rejected.

Fig 3 The single line diagram of 6-bus test system.

C. Analysis of the sub-processes involved

I. Pre-processing

The ECG is being captured with the appropriate devices such as 2-lead palm scanners and the processing begins. [For the study test, the ECG signals are taken from the Physionet Database files.]

The ECG signal is being extracted in the form of an image, and one of the image is as shown below:
The ECG image is being processed into RGB format and then converted to a gray-scale image. Morphological operations such as dilation and erosion are applied on this image inorder to improve the fine clarity on the edges of the ECG signal. For the morphological operations the structural element such as an identity matrix is being used.

The resulting image is as shown in fig 5:

II. Radon transform

The feature extraction is carried out with the Radon transform. Radon transform is the projection of the image intensity along a radial line oriented at a specific angle. The 2D Radon transform denoted as Ru (ρ, θ) is given by –

\[ R_u(\rho, \theta) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} u(x, y) \delta(\rho - x \cos \theta - y \sin \theta) \, dx \, dy \]

Here \( \rho \) is the perpendicular distance of a line from the origin and \( \theta \) is the angle formed by the distance vector. In the proposed technique we have taken \( \theta \) to be varying from 0\(^\circ\) to 180\(^\circ\).

If theta is a scalar, \( R \) is a matrix in which each column is the Radon transform for one of the angles in theta.

The Radon transform of an image is the sum of the Radon transforms of each individual pixel. The obtained Radon transform of the ECG image is as shown in Fig 6.

III. Feature vector extraction

The feature vector calculation is based on the Euclidian pair-wise distance calculation on the matrix obtained from Radon transform. This is carried out to find the distance between the pairs of pixels. The Euclidian pair-wise distance is as calculated:

Suppose the given \( m \times n \) data matrix \( X \) (in this case, image), which is treated as \( m \) (1xn) row vectors \( x_1, x_2 \ldots x_m \), the Standardized Euclidean distance between the vectors \( x_r \) and \( x_s \) is defined as –

\[ d_{rs} = \sqrt{(x_r - x_s)^T D^{-1} (x_r - x_s)} \]

Here \( D \) is the diagonal matrix with diagonal elements given by \( v^2_j \), which denotes the variance of the variable \( X_j \) over the \( m \) objects.

The output of the pair-wise calculation results in a feature vector.

IV. Distance classifier

This is the most important part of the biometric system, which takes the appropriate decision based on the algorithm defined.

For feature matching purpose, we design a distance classifier with a governing rule, which calculates the feature vector of each ECG entry stored in the system’s database and then compares it with that of the claimed person in a looping process. This computed comparative difference in the feature vector, when results in zero is noted and then by declaring as a
perfect match found for that individual and the system authenticates and grants the access.

If the difference is not as expected then the system clearly rejects the user’s access into the system.

IV. SIMULATION RESULTS

The performance of the ECG based Biometric system is found to be almost accurate to 99.999%. Since the feature matching is based on the comparison of the feature vectors of the claimed individual’s ECG and with that of the ECG image stored in the system’s database, the results are merely not on vector comparison, which increases the potential of the system, but the time taken to output the decision is proportional to the scale of implementation in a real scenario.

However with smaller scale implementation at different units of the organization will be much more effective and time conserving with much increased security and this can also clubbed with other biometrics for higher grade of security.

V. CONCLUSION

Through this paper, a new and a robust method of human authentication using ECG images is being proposed. The technique involves the Radon transform and Euclidean pairwise distance calculation methods in extracting the feature vector from the ECG pre-processed image.

As state, the implementation is easier in real time and also the time for the complete decisive output is based on the number of entries in the system’s central database as the feature vector is being calculated for every ECG entry in the database and then each of them is being compared in a one-to-one basis. Hence the time consumption is more, as the main motto for the biometric implementation in any organization is to slow down the instant access which may or may not be a threat to the system.

REFERENCES


