A Review of Gait Recognition Techniques and their Challenges

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ABSTRACT

Biometrics in user recognition systems are becoming increasingly important. There are three categories to biometrics namely; physiological, behavioral and token based. Physiological and token based biometrics are widely used in systems that need the user acknowledgement and cooperation for verification, however behavioural biometrics can be used to identify users without their knowledge and cooperation. Gait is a behavioural biometric that distinguishes an individual by the way they walk. Airports, banks and border control system could benefit dramatically from such systems. In this paper we look at techniques in model based and holistic approaches used in gait recognition systems. As well as their challenges and open issues.

KEYWORDS- Gait recognition, model and holistic approach

1. INTRODUCTION

In this technological age biometrics have proven to be one of the most reliable and accurate methods of identifying an individual. The recognition of the individual is based on feature vectors derived from the physiological and behavioural traits [1-3]. Unlike conventional authentication methods like personal identification numbers (PIN), smart cards, token keys etc. that can be lost, forgotten or even stolen, biometrics are unique and cannot be shared [4-6]. The physiological biometrics includes fingerprint, face, palm print, iris, retina and ear. These traits hardly change over time and remain permanent [7].

This category of biometrics usually needs the user’s presence, knowledge and cooperation for identification to be done.

Behavioural biometrics includes signature, speech, keystroke and gait[8]. However the focus is on gait in this paper. Gait is a biometric used to recognize and analyze the way a person walks [9]. Gait identification has been around for decades. More research still needs to be done around it however this does not mean it is unreliable. The advantage that gait has over other biometrics is that identification of individuals can be achieved without prior consent, users cooperation and knowledge [10]. Gait can be represented under two categories namely model based and holistic approaches. Under the model based approach a human body or part of it is used such as the body width, height, limb lengths, angular velocities and walking speed. However with the holistic approach there isn’t a model used rather a statistical factor of the recorded data. The paper is structured as follows section 2 of this paper introduces the gait recognition system and what it entails. Section 3 describes techniques involved in feature dimensionality reduction. Section 4 looks at the challenges in the gait recognition systems. Section 5 is the conclusion and summary of the paper.
2. GAIT IMAGE RECOGNITION SYSTEM

Biometrics have been around for decades and have proven to be reliable in identifying individuals. The biometrics includes fingerprint, palm print, hand geometry, ear, nose, retina, iris, signature, voice etc. Identifying individuals at a distance without their knowledge and cooperation is still however a problem for most of the biometrics mentioned above. Such a recognition system can be utilized in airports, boarder controls and banks. It is therefore imperative to use gait to identify individual at a distance [11]. Gait is a unique way in which each individual walks [12]. The gait recognition system is constituted by different stages. Figure 1 demonstrates stages involved in the gait recognition system.

2.1 Background removal

In image processing there usually is preprocessing of the image where the first step is segmentation. This refers to where the background is separated from the foreground to isolate the foreground. In the gait recognition system the same principle is employed. From the video frame work the moving objects are separated from the stationery one considered as the background. The background removal techniques:

2.1.1 Non recursive technique

A sliding window approach for estimating the background is used. This technique does not depend on the history apart from the frames stored in the buffer.

2.1.2 Recursive technique

On the other hand does the opposite; it does not maintain any buffer for background estimation. A Gaussian model is used to recursively update a single background model based on each input frame [13]. Post the background subtraction some noises maybe present, to alleviate the noise a filter such as a Median filter. Recursive techniques require less storage resources.

2.2 Feature extraction

Feature extraction plays an important role in the gait recognition system. Once the background is subtracted from the image, each image sequence is converted into a temporary sequence of distance signals. A feature of an image is represented using a vector. Silhouette is extracted; it is defined as region of pixels of walking person. There are different silhouette stances during gait cycle, they include midstance, double support etc. figure 2(a) demonstrates this different silhouette. Mostly used feature extraction approaches are namely model based approach and the non-modeled/holistic approach.
2.2.1 Model based approaches
In model based approach for gait recognition systems, models are employed whose parameters are determined using processing of gait sequences [8]. Using this approach requires high quality video sequences as it is scale and view invariant. The parameters used as features in the approach are the height, the distance between the pelvis and feet and the distance between the feet. The silhouette is divided into some regions. These regions are feature vectors that include averages of the centroid, the aspect ratio and orientation of the major axis of the ellipse. Example of this model is shown in figure 3. Figure 3(a) shows the distance between the pelvis and feet, the maximum distance between the heat and feet lastly the distance between the feet. Figure 3(b) shows the 7 regions of a walking human silhouette. Ellipses are put together and feature vectors are formed. They include averages of the centroid, the aspect ratio and the orientation of the ellipse. Figure 3(c) shows a hip rotation that is generated using a four series expansion of a signal. Figure 3(d) is a model using ellipses for the torso and the head, line segments for the legs and rectangular shape for the feet.

2.2.2 Holistic approaches
Holistic approaches focus on the shape of the silhouette or the motion of the whole body as compared to model based approaches that focus on a particular part of the body. These approaches are not dependent to quality of the video frame. Furthermore they offer less computational requirements and complexities. However they are usually not as robust as compared to model based approaches [14]. In holistic approaches the contour of the silhouette is regarded as an important factor of the method. It can be transformed to extract Fourier descriptors. For high quality silhouette the outer contour of silhouette is regarded the important feature. On the other hand binaries silhouettes are used for low quality silhouette as the important feature. Binary silhouettes are denoted as: $s[i,j], i = 0 \ldots, M - 1, j = 0, \ldots, N - 1$ where M, N denote the number of rows and columns of the silhouette, respectively.

Let $s[i,j] = \begin{cases} 1 & \text{if } (i,j) \text{ belongs to the foreground} \\ 0 & \text{otherwise} \end{cases}$

Using the above term, the horizontal and vertical projection of silhouettes are expressed as:
\[ P_a[i] = \sum_{j=0}^{N-1} s[i, j], \quad i = 0, 1, \ldots, M - 1 \]

\[ P_r[j] = \sum_{i=0}^{M-1} s[i, j], \quad j = 0, 1, \ldots, N - 1 \]

This feature is sensitive to silhouette deformations and this makes it efficient due to
the pixel being reflected in the horizontal or vertical projection as seen in fig 4(b). [17]
Proposed an angular transformation of silhouette, the silhouette gets divided onto
angular sectors and computes the average distance between foreground pixels and the
center \((i_c, j_c)\) of the silhouette Figure 4(c).

\[ A(\theta) = \frac{1}{N_\theta} \sum_{(i, j) \in F_\theta} s[i, j] \sqrt{(i - i_c)^2 + (j - j_c)^2} \]

Where, \(\theta\) is an angle, \(F_\theta\) is the set of the
pixels in the circular sector \([\theta - \Delta \theta/2, \theta + \Delta \theta/2]\).

![Figure 4. Representation of features extracted from binary silhouettes for gait. (a) width for silhouette (b) Horizontal and vertical projections (c) Angular representations.](image)

2.2.3 Comparison of approaches
The approaches possess different attributes, strengths and weakness. Table 1 compares
these approaches showing their advantages and disadvantages.

<table>
<thead>
<tr>
<th>HOLISTIC APPROACH</th>
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<th>Disadvantage</th>
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<td>Sensitive to structural differences</td>
<td>High complexity, low robustness</td>
</tr>
<tr>
<td>WIDTH</td>
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<td>SILHOUETTE</td>
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<tr>
<th>MODEL BASED APPROACH</th>
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<tr>
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<td>HIP ANGLE</td>
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3. FEATURE DIMENSIONALITY REDUCTION

After the feature extraction process, the features are extracted but they are at high dimensions which need to be reduced to decrease the failure of conventional classification algorithms. Thus the importance of the feature reduction algorithm, which only extracts the useful features for classification. The different techniques widely used for feature dimension reduction are as follows.

3.1 Principal Component Analysis (PCA)
PCA is a method that is used to simplify the data structure and still retain the original data as much as possible [12]. It is a method used to analyze data statically to find the principal component in which data is likely to vary. This method identifies patterns in data highlighting their differences variations. PCA can be used in image compression and pattern recognition algorithm. In a gait recognition system is used as a classical linear method to reduce data dimensionality while accounting for as data originality as possible.

3.2 Linear Discriminant Analysis (LDA)
LDA is an approach that is used in feature extraction specifically in the process of reducing the dimensionality of data. It performs training and projections on original gait feature [15]. It employs the use of PCA together with the LDA algorithm to reduce the dimensionality of data whiles preserving as much originality as possible.

3.3 Multiple Discriminant Analysis (MDA)
MDA is an approach where different class classifications are identified. In most cases three or classes are identified and classified. The objective of this technique is to maximize the distance between the different classes while minimizing the differences between the classes [15]. This technique allows for clearer generation of features while reducing the curse of dimensionality.

3.4 Combination of the approaches
In some cases the different techniques are combined to achieve certain required results. PCA and LDA are combined to improve the topology structure and reduce the dimensionality of the feature space. While in PCA and MDA are combined to process Gait Energy Image (GEI).

4. CHALLENGES IN GAIT RECOGNITION SYSTEMS
Gait recognition systems have been successful and proven to be accurate in identifying individuals; this however does not mean that there have not been challenges that are encountered in this field. These challenges can be classified under two categories based on how they affect a user’s body. They are classified as follows:

4.1 External factors
This are factors that surround the individual being identified such as lighting conditions, viewing angle, weather conditions, walking surface, clothes, shoe types, luggage being carried and so on.

4.2 Internal factors
Internal factors are those that affect the user’s body internally such as aging, sickness, drunkenness, weight gain or loss, pregnancy, accidents and so on.

All these factors as mentioned above affect the recognition of an individual in the gait recognition system.

5. CONCLUSION
This research paper is intended to show an overview of gait recognition systems, their challenges and open issues. It is evident that this form of biometric is maturing even though more research still needs to be carried out. At the moment gait recognition systems are best used when coupled with other biometric systems to have a bimodal system. In the near future gait recognition systems will be a force to be reckoned with. We hope that from this paper more research will be done to solve or remedy some of the problems exposed.

6. ACKNOWLEDGEMENT
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