Biometric Authentication Using Gait Features

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***Abstract*—Biometric Authentication systems are popular and effective for the greater degree of uniqueness among various people. Similar to any other biometric methodology, gait biometric is also an advanced biometric authentication methodology. Gait refers to the walking style of a person. The main advantage of gait authentication is that it is very difficult to imitate a person's walking postures to break into the system. Moreover there are no sensors used here as it reduces the cost and avoids the health hazards caused by the sensors. Authenticating the people from a long range is also another advantage of this method. A system is proposed that uses the height and maximum swing width along with chest width, shoulder width and velocity as the gait features to authenticate a person. The empirical results show that the system is successful in authenticating the person using the gait features used in the system.**

Keywords- Gait; Stride; Image Segmentation; Background Registration; Authentication; Biometric

I. INTRODUCTION

Biometric authentication systems make use of unique physiological or behavioral characteristics of the user. As of today biometrics is the most secure way to establish authentication. The biometric methods check for the physical presence of the specific user, whereas the knowledge/possession based methods are only capable of verifying the presence of the secret token.

The biometric methods can therefore establish a direct relation between the presence of the biometric trait and the person itself. It is thus not possible to hand over a biometric trait to someone else as it is with passwords or tokens. An additional peculiarity of all biometric methods is that they cannot rely on perfect agreement between the stored template and the newly acquired data. They have to tolerate a certain amount of variation in order to make allowances for natural fluctuations of the biometric trait [6].

A. Complex Technology

The relatively complex analysis of the behavioral and physical attributes with all their possible influences and natural variability of the biometric traits as well as ageing, make the biometric technology exclusive. Complicated schemes are necessary to compensate for all those effects [6].

B. Feature Extraction

The choice of the biometric methodology, i.e. feature (fingerprint, retina, iris, etc), is crucial. There has to be some kind of backup authentication because not every person has every biometric trait[3].

C. Gait Biometrics

Gait has several important properties that make it an interesting candidate as a biometric trait. First, people need not interact with a sensor in an unnatural way. In particular, they just enter a building through a hallway equipped with special sensors. The biometric system can then identify the passing person [6]. Second, gait implicitly performs a living subject to test and thus can neither be stolen nor lost. Last but not least, users do not need to unveil additional personal information about them that is not already available.

- The main objective is to propose and demonstrate the feasibility with a prototype system which is
- User friendly, in the sense that no other interaction with the system is needed other than walking.
- Robust, in the sense that valid users get access and impostors are rejected.
- Inexpensive, so that the final system may be of some practical and commercial relevance.
- Computationally efficient, so that the authentication delay is reasonable.

II. GAIT FEATURES

The walking style of a person is otherwise known as the GAIT of the person. There are about 24 gait features which will uniquely identify a person in this world [1].

A. Width Vector

An important issue in gait is the extraction of salient features that will effectively capture gait characteristics. In order to be robust to changes of clothing and illumination it is reasonable to consider the binarized silhouettes of the subject. We choose the width of the outer contour of the silhouette as the feature vector. The physical structures of the subject as well as the swing of the limbs and other details of the body are retained in the width vector. The width along a given row is computed as the difference in the locations of the right-most and the left-most boundary pixels in that row and a width vector is generated for each frame [4]. From the temporal width plots, it is clear that the width vector is roughly periodic and gives the extent of movement of different parts of the body. The brighter a pixel, the larger is the value of the width vector in that position.

B. Features derived from the basic width vector

One way to extract the dynamics is to compute the velocity profile by taking the difference of successive frames in the walking sequence. Obviously, most of the structural information like girth of the person is lost when we consider the velocity domain. It is to be expected that neither dynamic nor structural information, by itself, will be sufficient to capture gait. Both are necessary and cannot be decoupled. From the temporal width plot, we note that although the width vector changes with time as the person transits through a gait cycle, there is a high degree of correlation among the width vectors across frames. Most changes occur in the hand and leg regions [1]. The rest of the body parts do not undergo any significant changes during a gait cycle. It can be found in the temporal plot representation of width vectors and is shown in fig 1.

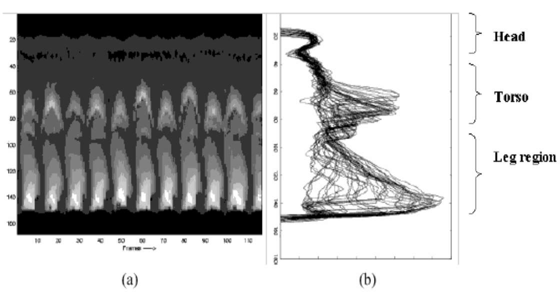

Figure 1. (a) Temporal plot of width vectors and (b) their overlay

C. Extracting Human Body Points

The mean dimensions of body height can be used to determine topological position of each body part in human figures. To extract the body points, the vertical position of the neck, shoulder, chest, pelvis, knees, and ankles for a body height *H* was estimated to be 0.870H, 0.818H, 0.720H, 0.285H, and 0.039H, respectively [4] as represented in the fig 2.

In the upper body region including head, neck, shoulder, and chest, the horizontal coordinate is calculated from two border points as

$$x\ center = xs + (xl - xs) / 2 \qquad (1)$$

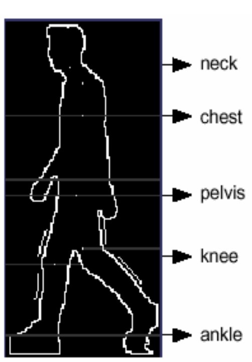

Figure 2. Extracting Human Body Points

where *xs* and xl represent the horizontal position of the first and the last pixels on the scan line respectively. The waist and pelvis coordinate is calculated by interpolation from the coordinates of the shoulder and chest as

$$xpelvis = \frac{xchest + ((xchest - xshoulder)}{(ychest - yshoulder)) (ywaist - ychest)} \qquad (2)$$

Human walking involves rhythmic up-and-down displacement of the upper body (from pelvis to head), hence the apparent bobbing of the head. Furthermore, these vertical movements occur in a smooth sinusoidal manner for the conservation of energy . Thus, the apparent height of a walking person can be modeled as a sinusoidal curve:

$$h(t) = \mu_h + \alpha_h \sin(\omega t + \phi) \qquad (3)$$

The maximum height, $\mu_h + \alpha_h$, occurs at the *mid-stance* phase of walking (when the legs are closest together), and is slightly smaller than the person's stature (i.e. standing-height), typically within less than 1 cm. The minimum height, $\mu_h - \alpha_h$, occurs at the *mid-swing* phase of walking (when the legs are furthest apart). Assuming the person is sufficiently far from the camera (i.e. orthographic projection applies), the apparent height at any time can be estimated from an image as:

$$h = \frac{Z \frac{h_{im}}{f}}{\cos\theta_v - \frac{y + h_{im}}{f} \sin\theta_v}$$

where y and h_{im} are respectively the person's vertical position and height in the image, θ_v is the tilt angle, f is the camera focal length, and Z is the distance from camera center to the person. The person's height in the image is taken to be the bounding box height of the binary silhouette [6].

III. EXPERIMENTAL SETUP

A person (testing subject) is made to pass through the web camera and his video is captured. The person's image is segmented from the video using the Background Registration Technique [8] and Graph cut algorithms [5] [12]. The mask of the person is used to identify [4] the various gait features like height, maximum swinging width, chest width, shoulder width, and speed of walking of the person. These details are stored and registered in a database.

When the same person walks in front of the camera his gait features are computed in real time and is compared with the template available in the database and if it matches, the person is authenticated. The architecture of the proposed system is given in the fig 3.The Graphical User Interface of proposed system is shown in the fig 4.

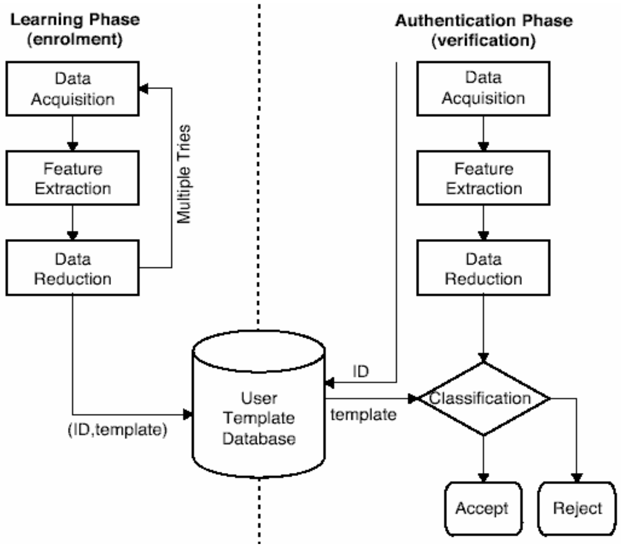

Figure 3. Architecture of GAIT Biometric Authentication System

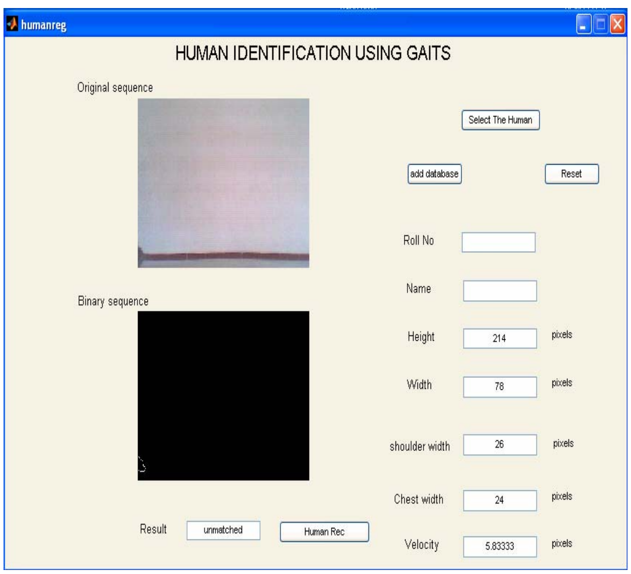

Figure 4. Gait feature Extraction (*GUI*)

A. Stride analysis

The stride analysis variables most commonly used to describe a gait pattern:

- Step length is the distance between the point of initial contact of one foot and the point of initial contact of the opposite foot. In normal gait, right and left step lengths are similar [11].
- Stride length is the distance between successive points of initial contact of the same foot. Right and left stride lengths are normally equal.
- Cadence or walking rate is calculated in steps per minute.
- Velocity, the product of cadence and step length, is expressed in units of distance per time. "Free speed" refers to the individual's comfortable walking speed. Since individuals walk at different speeds depending on the situation, normal velocity values are somewhat arbitrary.
- Walking base is the sum of the perpendicular distances from the points of initial contact of the right and left feet to the line of forward progression.

Following are the stride analysis variations seen for males and females:

TABLE I. MEAN STRIDE ANALYSIS BETWEEN MALES AND FEMALES

Gait parameters	Males	Females
Step Length (cm)	79	66
Stride Length (cm)	158	132
Cadence (steps/min)	117 (60-132)	117 (60-132)
Velocity (m/sec)	1.54	1.31
Walking Base (cm)	8.1	7.1
Foot angle	7	6

The basic idea of our segmentation algorithm is change detection. The moving object region is separated from other part of the scene by motion information [10]. However, unlike other change detection based approaches, our judge criterion for motion does not come directly from the frame difference of two consecutive frames [11].

IV. BACKGROUND REGISTRATION

In the background registration step, the history of frame difference mask is considered in constructing and updating the background buffer. A stationary map is maintained for this purpose. If a pixel is marked as changing in the frame difference mask, the corresponding value in the stationary map is cleared to zero; otherwise, if the pixel is stationary, the corresponding value is incremented by one [8]. The values in the stationary map indicate that the corresponding pixel has not been changing for some consecutive frames.

If there is no change in the current pixel and if a pixel is stationary for the past several frames, then the probability is high that it belongs to the back-ground region. Therefore, if the value in the stationary map exceeds a predefined value, denoted by, then the pixel value in the current frame is copied to the corresponding pixel in the background buffer. A background registration mask is also changed in this process. The value in the background registration mask indicates that whether the background information of the corresponding pixel exists or not. If a new pixel value is added into the background buffer, the corresponding value in the background registration mask is changed from non-existing to existing [8].

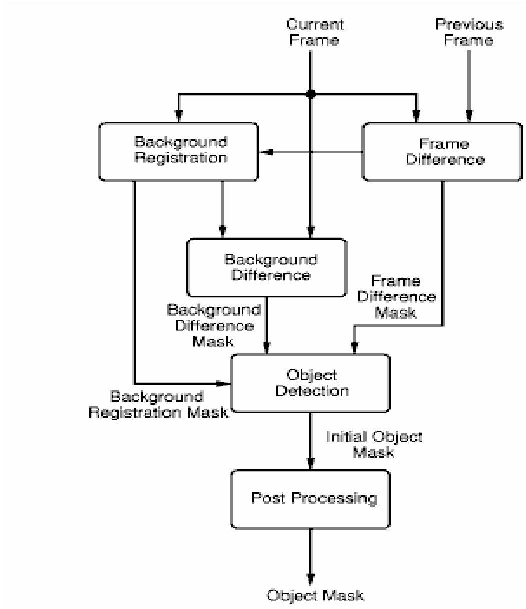

Figure 5. Block Diagram of Video Segmentation Algorithm

A. Background Difference

This step generates a background difference mask by threshold the difference between the current frame and the back-ground information stored in the background buffer. This step is very similar to the generation of frame difference mask. The threshold value is also determined by the required significance level [8].

TABLE II. OBJECT REGION DECISION

Index	**Background Difference**	**Frame Difference**	**Region Description**
1	N/A	$\|FD\| > TH_{FD}$	Moving
2	N/A	$\|FD\| \leq TH_{FD}$	Stationary
3	$\|BD\| > TH_{BD}$	$\|FD\| > TH_{FD}$	Moving Object
4	$\|BD\| \leq TH_{BD}$	$\|FD\| \leq TH_{FD}$	Background
5	$\|BD\| > TH_{BD}$	$\|FD\| \leq TH_{FD}$	Still Object
6	$\|BD\| \leq TH_{BD}$	$\|FD\| > TH_{FD}$	Uncovered Background

B. Object Detection

The object detection step generates the initial object mask from the frame difference mask and the background difference mask. The background registration mask, frame difference mask, and background difference mask of each pixel are required information.

Table II. Lists the criteria for object detection, where BD means the absolute value of difference between the current frame and the background information stored in the background buffer, FD is the absolute value of frame difference, and the OM field indicates that whether or not the pixel is included in the object mask. TH_{BD} and TH_{FD} are the threshold values for generating the background difference mask and frame difference mask, respectively [3].

For the first two cases listed in Table 2, the background information is not yet available, so the frame difference information is used as the criterion for separating object from background [8]. Although only change detection is used in these situations, the background registration keeps accumulating the background information, and hence the number of pixels without background information reduces rapidly [2].

For cases 3 to 6 in the decision table, the criterion is background difference because the background information exists. If both the frame difference and the background difference are significant, the pixel is part of a moving object. On the other hand, if both the frame difference and the background difference are insignificant, the pixel should not be included in the object mask. Therefore, for the third and fourth cases in Table 2, our result is the same as the result of using only the frame difference for change detection. In our algorithm, the uncovered background region is handled correctly because we recognize that this region matches the background information even though frame difference suggests significant motion.

V. CONCLUSION

A parametric approach for human identification using height and stride parameters for walking gaits achieves its accuracy by exploiting periodic nature of human walking and computing the gait features over many steps. This work shows height and stride are the useful discriminates for person identification. The best approach may be combinational features of biometrics such as face recognition, etc along with the gaits.

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