A Model Based Approach for Gait Recognition System

Mohamed Rafi, Hédi Khammari, R.S.D Wahidabanu, Yasmeen Taj

Abstract— In this paper, we propose a model based approach for gait recognition using the mathematical theory of geometry and image processing techniques. In such approach, feature matrices used for gait recognition are constructed using segmentation, Hough transform and corner detection techniques. Indeed, it is possible to recognize a subject by analyzing the gait parameters extracted from his footsteps taken in different frames. In the preprocessing stage, the picture frames taken from video sequences are inputted to Canny Edge detection algorithm in order to detect the image edges and to reduce the noise by means of Gaussian filtering. The Hough transform is then applied to isolate the features of the preprocessing output and to get a gait model. The latter is used to extract the gait parameters, and the Harris Corner Detection technique is used to detect the corners and to generate the feature points. The gait parameters are measured by means of feature points and then stored in a gait database. Using a gait recognition interface the random subjects parameters are compared against a template set in the available database for recognition. In the proposed method, we have considered a database including ten subjects and a five parameters based gait recognition system. It is worth noting to remark that when the camera is placed at 90 and 270 degrees towards the subject, all the recognition parameters are clearly visible, measurable and lead to have more than 80% accuracy in recognition results.

Keywords— Biometric, Gait recognition, Canny Edge Detection, Hough Transform, Harris Corner Detection

I. INTRODUCTION

Nowadays security plays important role in almost all areas mainly in public places. Biometrics used to analyze and measure biological data namely human body characteristics, are well suited for security issues, among such biometrics gait recognition is quite promising.

Gait recognition is a soft biometric for identifying an individual by the manner in which they walk. Identification of people at a distance can be achieved via an unobtrusive biometric without any interaction or co-operation from the subject. Considering gait motion biometric is motivated by the availability of surveillance cameras in most of the security places, besides this method does not need person or subject Involvement. Gait biometrics includes face recognition which is capable of recognizing only frontal or nearly frontal faces. Other biometrics such as fingerprint and iris are no longer applicable when the persons suddenly appear in the surveillance [1].

Aiming to identify human gait motion, we propose a new model based method using segmentation, Hough transform and corner detection techniques.

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Thereby the gait pattern is incorporated to establish a model used for tracking and detection of gaits. The proposed method permits to extract accurately moving leg joints of human for indoor and outdoor data filmed in an unconstrained environment. Essentially [2], the human gait model describes a moving line whose inclination is constrained by a periodic signal and velocity governed by some initial conditions and characteristics [10]. Then the model parameters are extracted and the feature points of images are produced by Harries Corner detection algorithm. Using feature points the feature matrices are constructed and stored in a gait database for further processing. Analysis of the extracted gait parameters in different picture frames, leads to identify individual person. In this research, based on the articulated-models approach, we use images captured from different views as the image captured from the frontal or perpendicular view does not give required signatures. Segmentation is performed on the captured image in order to distinguish foreground from background using canny edge detection technique. Aiming to build the gait model the output of segmentation is processed using Hough Transform Algorithm. In the following we use five parameters for proposed gait recognition approach namely distance between legs, right knee angle, left knee angle, left thigh length and right thigh length as shown in fig 1.

In the remaining, section 2 is devoted to general reminders; section 3 is dedicated to the methodology. The proposed geometric model is described in section 4 and finally the results are given and discussed in section 5.

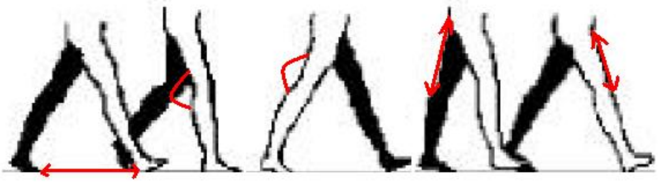

Figure. 1: Different walking style and gait parameters. [a] distance between legs [b] right knee angle [c] left knee angle [d] left thigh length [e] right thigh length. [15]

II. GENERAL REMINDERS

The need for automatic human identification system in many applications is of paramount importance, especially at a distance and has recently gained a great interest from the image processing, pattern recognition and computer vision researchers as it is widely used in many environments concerned with security issues namely the banks, the parks and the airports [3].

Much ink has been spilled on this question, but very limited success is reported in the area of gait extraction. The first scientific article on animal walking gaits has been written 350BC by Aristotle, translated by Farquharson [4]. He observed and described different walking gaits of bipeds and quadrupeds and analysed why all animals have an even number of legs.

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Recognition approaches for the gait motion have been developed in the 1990s, their evaluation to small databases has given good results.

The human identification at a distance (ID) program(DARPA) proposed by S. Sarkar et al. in[5] which collected a rich variety of data and developed a wide variety of technique showed that gait could be extended to large databases and could handle covariate factors.

Other methods of gait recognition not familiar with shape were reported in [6]. Such methods including symmetry analysis, universal symmetry or balance operator are using features related to universal properties of their own rather than general appearance.

On each frame of the test object the evaluation procedure consists in masking rectangular block of a certain width at the same position. For a bar size of 5 pixels, 100% accuracy rate in gait recognition were reached.

Recognition accuracy was said to be seemingly adversely affected when the subject is walking behind a vertically placed object. Other limitations related to legs tracking were considered not enough for a high standard gait recognition were reported in [7]. The segmentation process leads to a very rough model fitting procedure which in turn adversely affects the rate of recognition. In certain methods of gait recognition, the captured video of subjects takes into account the fact that the subjects are walking perpendicular to the camera [8].

In real life this would not be the case as people walk all angles to the video camera. Also the major drawback found is using of few parameters for gait recognition which is required to be addressed.

A technique by Cunado et.al[9] uses hough transform to extract lines that can be used to represent legs , later Fourier analysis is applied to the resulting joint angles for gait recognition.

However the limitations that are intrusive in these techniques makes the use of sophisticated computer vision system to produce gait parameters that describes the gait motion. In gait recognition of human identification based on silhouette analysis, a combination of simple correspondence and back ground subtraction is used to track and segment spatial silhouette of an image. But this approach produces more noise which lead to poor gait signature extraction, therefore the recognition rate is low. Also the major drawbacks of these appearance based approach is that they are usually designed only for a specific view point, generally front to parallel.

Based on body joint position, Wang [10] presented simple and efficient gait recognition approach for 10 subjects. In this approach the joint coordinates are calculated according to the geometrical features that are observe during walking. The limb angles are calculated based on the coordinates of joints and than applying Discrete Fourier Transform. The amplitude frequency and phase frequency of angles are used as gait features and the recognition rate of 78% is obtained using this approach.

Another statistical approach for dynamic signature extraction of gait on 10 subjects was presented by Yanmei, jinchaun, Rongchun and J. Jia [11]. In this approach on each of the pixel position the Dynamic Variance Matrix(DVM) for a complete gait sequence is primarily extracted and then calculated their Variance Features(VF) to design a DVM as a gait signatures for recognition and obtained 76% recognition result.

The motivation behind this research is the importance of Identification and Recognition of the subject or person accurately and efficiently. Many security required environments such as military installations, banks and airports required quick detection of threats and need to provide different levels of information to many user groups of different type and also the major motivation is the installation of video recording surveillance cameras in most buildings or locations requiring a security presence, the available videos are just needs to be checked against of the suspect. As well as the increase in processor power, along with the fall in price of high speed memory and data storage devices have all contributed to the increased availability and applicability of computer vision and video processing techniques, real time video processing, which is required for gait recognition system.

The objective of this paper is to describe new model based approach for gait recognition system from a sequence of images of a walking subject without using markers. And to develop sophisticated image processing techniques to extract gait signatures that can be used for person recognition.

In our previous study [12] & [14], we detect the gait parameters in terms of clarity using Hough transform, and measure the gait parameters using the theory of geometry where the corners are detected using harries corner detection technique & proposed for further improvement. In the proposed study, the measure parameters of 10 subjects are stored in a gait database and the gait recognition interface is designed. Using this interface random subject can be checked for recognition against the available gait database.

III. THE PROPOSED MODEL FOR GAIT RECOGNITION SYSTEM

We propose model a based approach for gait recognition, in which the feature extraction uses a priori knowledge of the object which is searched in an image scene. This approach permits to extract the feature points or parameters from the video footage. When human body is modelled, there are various physical and kinematical constraints which are realistic and can be taken into account in the model.

A biometric produced by a model based approach has high dependability on the original data. Using video feeds from conventional cameras and without using a special hardware, implicates the development of a body motion capture system.

For gait recognition, the proposed approach includes uses components such as gait capture, image segmentation, feature extraction, gait database and gait recognition interface.

A. Gait Capture and Segmentation

At this stage the subjects are asked to walk for capturing of gait motion. The gait of an individual is then viewed by means of a video sequence. The videos will be taken from two angles namely 90 and 270 degrees. Thereby, a clear signature of each subject is obtained, and the video is converted into frame by frame pictures stored in an intermediate format (jpg). Afterward, these pictures are loaded by the program for processing. That is to say the indexed image is the input to the segmentation algorithm using the canny edge detection implemented as follows [13].

Let $I(x,y)$ denotes the recorded image. The Gaussian filter L having (x,y) dimensions WxW, has the form:

$$L_\sigma(x,y) = \nabla(I(x,y) * G_\sigma(x,y)) \quad (1)$$

where σ is the size of the window, ∇ denotes the gradient operator implemented by convoluting the image with a central difference filters: $h_x(x,y)$ = [1 0 -1] and $h_y(x,y)$ = [1 0 -1]^t.

The Gaussian function is defined as

$$G_\sigma(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{(x^2-y^2)}{2\sigma^2}}$$

Equation (1) describes the filtered image at pixel p.

Edge points within the filtered image are given by the following equation:

$$E_\sigma(x,y) = \| L_\sigma(x,y) \|^2 \quad (2)$$

The Edge points are thinned as in the canny edge detector [11], by locally applying non-maximum suppression in the direction of the computed image gradient ∇.

Finally, a set of candidate corner positions, $E'(x,y)$ok, is generated by discarding all edge points having magnitude less than the average edge magnitude value over the entire image is in the form

$$E_\sigma{}'(x,y) = \{E_\sigma(x,y) \mid E_\sigma(x,y) > \overline{E_\sigma(x,y)}\} \quad (3)$$

where

$$\overline{E_\sigma(x,y)} = \frac{1}{N}\sum_x \sum_y E_\sigma(x,y)$$

The results of pre-processing the image are shown in figure2 [10].

Figure. 2: image of a walking person. RGB to Grayscale (left),Edge Detected Image (right)

B. The Feature Extraction

In image processing and pattern recognition fields, feature extraction is a type of dimension reduction in which the input data is converted into feature sets. Hough transforms and corner detection techniques are applied in the proposed approach for feature extraction. The Hough transform is mainly used to produce an image model able to extract relevant gait features for recognition. Once the model is fitted to the image, the gait signature features can be derived from the model namely the thigh length variation, the knee angles, and the distance between legs for different frames.

The output of the canny edge detection bloc is inputted to the Hough transform unit which outputs a gait model as shown in figure 3[12]. Such model is then used as an input to the corner detection bloc.

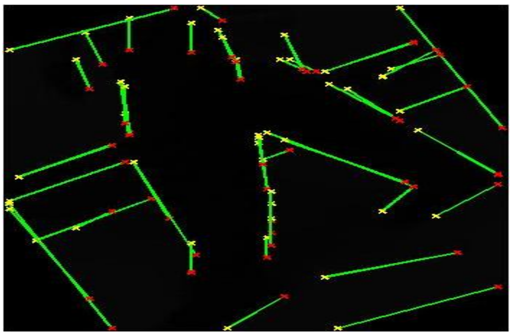

Figure. 3: Gait Model after Hough

The most popular approach for corner detection is the Harris corner detector originally proposed in [14] for which there now exist many variants. A Harris corner detector takes the current pixel and examines the changes in intensity over different directions by examining the autocorrelation function as shown in equation 4, where the shift $(\Delta x, \Delta y)$, a point (x, y) and the intensity of the pixel is given by I(x,y). The points (x_i, y_i) are within the Gaussian window W centered on (x, y).

$$c(x,y) = \sum_{(x_i,y_i)\in W} [I(x_i,y_i) - I(x_i+\Delta x, y_i+\Delta y)]^2 \quad (4)$$

Substituting equation 4 with a Taylor expansion of the shifted image reveals equation 5.

$$c(x,y) = [\Delta x \Delta y]\begin{bmatrix} \sum_w ((I_i, y_i))^2 & \sum_w I_x(x_i,y_i) I_y(x_i,y_i) \\ \sum_w I_x(x_i,y_i) I_y(x_i,y_i) & \sum_w ((I_i,y_i))^2 \end{bmatrix}\begin{bmatrix}\Delta x \\ \Delta y\end{bmatrix}$$

$$c(x,y) \cong [\Delta x \Delta y] M \begin{bmatrix}\Delta x \\ \Delta y\end{bmatrix} \quad (5)$$

A corner (or in general an interest point) is characterized by a large variation of c in all directions of the vector (x , y). By analyzing the eigenvalues of M, this characterization can be expressed. Let λ_1, λ_2 be the eigenvalues of M. Then describe a point in terms of eigenvalues of M is the measure of corner response

$$R = \lambda_1\lambda_2 - k(\lambda_1 + \lambda_2)^2 \quad (6)$$

The output of the Harries corner detector on every frame t from the edge detected image is

$$C_i = \sum_{t=1}^{N} H(I_t) \quad (7)$$

Where H is the output of the Harris corner detector, I_t is edge detected image at frame t.

The proposed model base approach for gait recognition system is given in Figure. 4

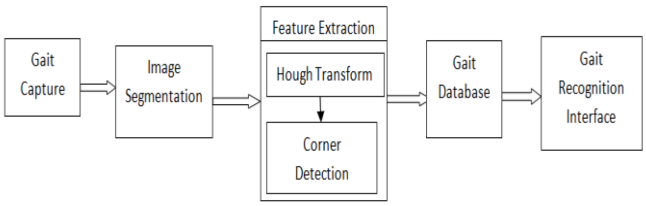

Figure. 4: Components of the proposed model for Gait Recognition System

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IV. PROPOSED GEOMETRIC MODEL

In the proposed model based approach, a structural model of leg is developed as shown in figure 4. From the model, the gait parameters are measured using geometry. This model can be made up of drawing lines and angles that describing the edge of the different leg parts.

Figure 5 shows the representation of leg in terms of lines that connects hip, knee and ankle, respectively. The thigh is the distance between hip and knee

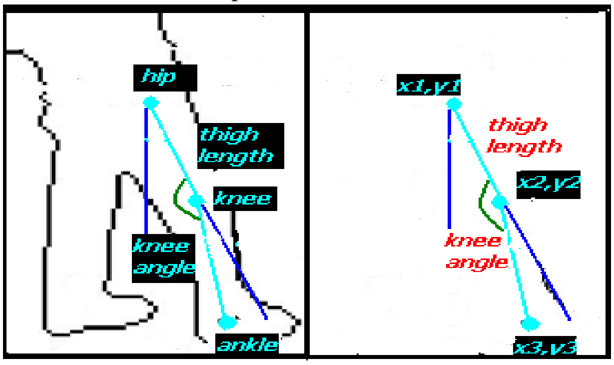

Figure. 5: Structural model of a human right leg. [15]

. Let the hip and knee edges are defined by (x_1,y_1) and (x_2,y_2), the distance $\Im$ (thigh length) is measured using Euclidean distance formula as

$$\Im((x_1,y_1),(x_2,y_2)) = \sqrt{(x_1-x_2)^2+(y_1-y_2)^2} \text{ pixels} \quad (8)$$

The knee angular distance (knee angle) is measured as

$$\theta(x_2,y_2) = \tan^{-1}\frac{m_1-m_2}{1+m_1.m_2}\times\frac{180}{\pi} \text{ degree} \quad (9)$$

where slopes m1 and m2 are defined as $m_1=(x_2-x_1)/(y_2-y_1)$ and $m_2=(x_3-x_2)/(y_3-y_2)$ and (x_3,y_3) is ankle edge.

V. RESULTS AND DISCUSSIONS

The Digital camera is used to collect the data. The camera is placed in angles 90 degree and 270 degree normal to the subject's path in an environment with controlled illumination. Data collection is performed indoors, with lighting at a constant level. Subjects walked in front of a plain, static background. Fig. 2 shows an example image frames of a walking person (person 1) used in this study. Each subject is asked walk past the camera a total of five times. From these five sequences, the first and last three are discarded and only the middle four sequences are used for experimentation. In the first few sequences the subject would be getting comfortable with the experiment, and in the last few the subject would be anxious to finish the experiment. As such, the middle four sequences were considered to offer the most consistent walking cycles. In all, 20 walking trials were completed, yielding the events for subsequent data analysis. This is a very important step as the total result depends on the quality of the gait captured. So the care should be taken to see that the quality of gait capturing is maintained, this step includes video sequence and data store in the gait database. All post-processing and analysis was carried out off-line using the **MATLAB programming environment.**

To demonstrate the efficiency of this approach, we have run the algorithm on a set of 10 different subjects. Tables 1-6 illustrate the number of parameters which are used to generate a gait signature for different view of different subjects in different frames.

The parameters like Right thigh length, left thigh length and distance between legs are measured in terms of number of pixels and the parameters right knee angle and left knee angle are measured in terms of degree. The corner detection technique gives approximate and nearest feature point for different gait parameters from which feature matrices are constructed that can be used for gait recognition of individual. The distance is measured using Euclid distance formula. From tables 1-6 for Subject 1, Subject 2 and Subject 3, when the camera is placed at 90 degree and 270 degree it is found that most parameters are measured successfully and values difference of some parameter like distance between the legs is same for some frame and in some frame we can find only minor difference for some parameter like right thigh length and left thigh length that to be because of poor data processing.

Table 1: Gait parameters measured values for subject1 when camera is placed at 90 degree

Frame	Length of Right thigh(In terms of Pixels)	Length of Left thigh(In terms of Pixels)	Knee Right Angle(In terms of degrees)	Knee left Angle(In terms of degrees)	Distance between Legs(In terms of Pixels)
1	63	62	39	-34	126
2	62	63	38	-40	125
3	66	66	41	-43	129
4	63	64	39	-41	125
5	62	65	40	-42	127

Table 2: Gait parameters measured values for subject1 when camera is placed at 270 degree

Frame	Length of Right thigh(In terms of Pixels)	Length of Left thigh(In terms of Pixels)	Knee Right Angle(In terms of degrees)	Knee left Angle(In terms of degrees)	Distance between Legs(In terms of Pixels)
1	51	47	-43	31	137
2	56	53	-19	31	136
3	54	45	-5	24	138
4	53	48	-4	28	137
5	54	47	-5	26	138

Table 3: Gait parameters measured values for subject 2 when camera is placed at 90 degree.

Frame	Length of Right thigh(In terms of Pixels)	Length of Left thigh(In terms of Pixels)	Knee Right Angle(In terms of degrees)	Knee left Angle(In terms of degrees)	Distance between Legs(In terms of Pixels)
1	65	66	37	-30	138
2	67	69	36	-27	140
3	60	61	45	-32	138
4	65	68	40	-31	138
5	67	69	42	-30	140

Table 4: Gait parameters measured values for subject 2 when camera is placed at 270 degree

Frame	Length of Right thigh(In terms of Pixels)	Length of Left thigh(In terms of Pixels)	Knee Right Angle(In terms of degrees)	Knee left Angle(In terms of degrees)	Distance between Legs(In terms of Pixels)
1	74	68	-5	20	150
2	77	73	-22	29	152
3	77	74	-12	28	146
4	76	72	-14	27	148
5	77	74	-12	28	150

Table 5: Gait parameters measured values for subject 3 when camera is placed at 90 degree.

Frame	Length of Right thigh(In terms of Pixels)	Length of Left thigh(In terms of Pixels)	Knee Right Angle(In terms of degrees)	Knee left Angle(In terms of degrees)	Distance between Legs(In terms of Pixels)
1	91	95	-3	18	159
2	92	88	-2	1	158
3	95	92	-8	3	158
4	94	91	-7	5	159
5	95	92	-8	7	159

Table 6: Gait parameters measured values for subject 3 when camera is placed at 270 degree

Frame	Length of Right thigh(In terms of Pixels)	Length of Left thigh(In terms of Pixels)	Knee Right Angle(In terms of degrees)	Knee left Angle(In terms of degrees)	Distance between Legs(In terms of Pixels)
1	91	77	-18	18	158
2	92	73	-28	28	158
3	95	77	-8	30	158
4	94	78	-18	28	158
5	95	77	-8	27	158

The measured parameters of 10 subjects taken by placing camera in 90 degree and 270 degree are stored in a gait database. Table 7 & 8 gives the gait values stored in a database for 10 subjects for frame 1 taken by placing camera in 90 & 270 degree. The subject is checked for recognition by comparing captured image gait values with the available gait database values using the Gait Recognition Interface, shown in Figure 6.

Table 7: Gait database values for 10 subjects for Frame 1taken when camera is placed at 90 degree

Sub ject	Right thigh Length (In terms of Pixels)	Left thigh Length(In terms of Pixels)	Right Knee Angle(In terms of degrees)	Left Knee Angle(In terms of degrees)	Distance between Legs(In terms of Pixels)
1	55	55	2	-34	103
2	75	76	37	-30	138
3	80	77	-18	18	158
4	60	62	20	-24	160
5	65	66	25	-30	154
6	75	74	40	15	137
7	86	85	-19	-25	145
8	50	51	30	-30	152
9	53	54	37	18	103
10	60	62	32	-24	139

Table 8: Gait database values for 10 subjects for Frame 1taken when camera is placed at 270 degree

Sub ject	Right thigh Length(In terms of Pixels)	Left thigh Length(In terms of Pixels)	Right Knee Angle(In terms of degrees)	Left Knee Angle(In terms of degrees)	Distance between Legs(In terms of Pixels)
1	54	55	-33	7	102
2	76	74	-30	37	138
3	77	80	22	-19	158
4	63	60	-22	21	160
5	66	63	-30	27	155
6	74	75	18	41	137
7	82	83	-24	-17	146
8	53	50	-32	31	152
9	54	53	18	37	104
10	60	60	-24	32	139

A. Gait Recognition Interface

Using gait recognition interface we are recognizing each subject. The subject to be check for recognition is randomly submitted as input through gait menu. The interface is designed in such a way that it accepts input and when we click recognition button it checks the given input for recognition from the available gait database. If the match is found it displays recognized image in the display area on the screen, if the input is not matched with the available database, it display the recognition is unsuccessful. Both are shown in figure 6 & 7

B. Successful Gait Recognition

Figure.6: Gait Recognition Interface (Recognition Successful)

C. Unsuccessful Gait Recognition

Figure.7: Gait Recognition Interface (Recognition Unsuccessful)

Table 9: Recognition Result Compared with Other Methods

SL no	Method Name	Database Size	Recognition Result(Camera placed at 90 Degree)	Recognition Result(Camera placed at 270 Degree)
1	Our Method	10	85%	80
2	Local Binary Pattern Variance	10	78%	-
3	Positioning Human Body Joints	10	76%	-

D. Proposed Method Advantages

In the proposed method model is generated for each Image, Memory Space required is less because of numeric values comparisons, Rate of recognition is better than other methods and also silhouette images are not required

VI. CONCLUSION & OPENINGS

This research has shown that better gait recognition rate can be achieved by using proposed approach. When the camera is placed at 90 and 270 degrees it is found that most parameters listed in the research are measured successfully and we can get recognition rate more than 80%. The proposed research gives highest results if the subjects must be made to pass through a area which has a white background because it will help in getting a better segmentation. The research achieved successful gait parameter measurement if the parameters length of left, right thigh and distance between the legs are analysed at 90 degree and 270 degree camera placement.

In future work the gait database size can be improved by improving model fitting and by using better segmentation approach.

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