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AN AUTOMATIC HUMAN GAIT RECOGNITION SYSTEM BASED ON JOINT ANGLE ESTIMATION ON SILHOUETTE IMAGES

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ABSTRACT

Gait recognition as a biometric attribute has the capability to be recognized in monitoring systems. In this paper, a method based on joint angle estimation of body motion for gait recognition is proposed. The representation of gait feature for the motion angles of upper and lower of body part is investigated and joint angle is calculated using Fourier, radon and Gabor features. Based on the joint angles estimation, we build a histogram of the feature individually. In the measurement stage of distance, $\chi 2$ function is used to measure the similarity between these histograms. After that, a classifier is built to implement the stage of classification. Experiments were tested on CASIA (B) Database to demonstrate that proposed method can attain a high-quality recognition performance.

Keywords: *Gait Recognition, Silhouette, Joint Angle, Skeletonization, SVM.*

1. INTRODUCTION

According to [1], biometric shows the humans' identification through their characteristics or features. In addition to face, characteristics include fingerprint, DNA, Iris, and gait. However the methods of the recognition currently, such as face recognition, iris recognition or fingerprint recognition based, require a physical contact or cooperative subject. So it is difficult to identify individuals by using these methods at a distance. However, gait as a feature of persons walk does not have these constraints. [2] said that many studies have previously submitted evidences on the merits of the manner of walking as an influential biometric in close watch (surveillance) and the access monitoring. The influential biometric method has a diversity of advantages including noninvasive, its resistance to keep from sight and having the ability to be obtained at a space. Furthermore, [3] stated that gait could be used in the medical field. He identified gait as: "it is ideally suited method to recognize people at unfixed distance". For example, the early changes recognition in the walking patterns assists in identifying varied situations, for example, the disease of Parkinson and the earliest stages of the progressive disease that called multiple sclerosis. Despite the fact that gait might not consider distinctive as the features of fingerprint or iris that could affect by shoes, clothing or physical cases of one, it considers unique as well as valuable in the visible observation by the virtue of the inherent gait characteristic of a human being [2].

Nowadays, videos are not the only mean to collect the gait any more. [4] said that as stated in the technique of data collection, the methods of gait recognition include three methods including Video Sensor (VS), Wearable Sensor (WS) and Floor Sensor (FS) [4]. In the method that based on VS, video cameras are used to collect the data of gait. At the absence of physical contact, this method is considered noninvasive and its work may limit to the walking of persons in the natural way. In addition, in our daily life, video camera is used commonly. It is somewhat very easy to obtain the data of gait in different occasions. Yet, the processing of images is required, and the images that resulted from cameras should preprocess to find the information of gait that may utilize in a

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straight. Thus, in a remote monitoring, the VS is used widely. The second method is WS, it requests the sensors to identify the wear and motion of the data collection that recorded by them. The single difference between the two methods VS and WS is that the motion data in WS could be obtained at once, and the resulted data is appropriate for the analysis of gaits. In fact, WS is commonly used in the analysis of gaits mainly in the medical fields. Yet, it is lack the key feature of non-invasive. Therefore, it is not use in the remote monitoring. So, 2D has the capacity to indicate to the specific data of gaits. So, the data resulted from of 2D could be recognized by the sequence of images that used broadly in the past. The third method called FS or footprint; it makes use of the sensors that put on the floor. The information on site and length of one's footprint are to be recorded for intending the study [2].

This study proposes an efficient feature representation and classification method to preserve high accuracy recognition result with low feature dimensionality. The study proposes an intelligent authentication of the application of a human being diverse features extraction. In this research, it is tried to conduct a human gait recognition based on spatial and temporal analysis of silhouette contours and joint angles on the CASIA Gait Data Base.

The method that proposed in this paper is based on joint angle estimation of the body walking for gait recognition. This method is to be effective if applies on database of 2D video. The angles' motion for upper and lower parts of body from the original data is extracted to suggest the new feature. Thus the joint angle spectrums can be work out by which the vector feature is produced. Then, the feature of histogram is built, and the distance that exists between the histograms is calculated. Finally, the classification is implemented on the vector of distance aiming at distinguishing gaits.

In short, this paper is included several section. The first section includes background of the intended topic. In section two, the related works are to be discussed. Section three shows the feature of definition and extraction. The classification is to be described in section four. In addition, section five presents the experiments and the results. Finally, the conclusion of the paper is to be shown in the section six.

2. RELATED WORKS

Gait recognition methods have been examined competently. Several processes relate to the main method have been also developed. In the opinion of [5], approaches are divided into varied models, such as model-based, model-free and multi-information fusion. In the view of [6] and [7] model-based approaches in which gait signatures are constructed by modeling. Within the model-free approaches, [8] ignored the human body structure in favor of silhouette that based on representations and varied information fusion approach in order to reproduce human vision perception through utilizing the biometrics or double, face for instance.

In the previous days, the model-free approaches expanded due to its rapid development. In this context, [9] raised a recognition resulted from shape analysis-based method. He displayed the silhouettes changes in the static pose through time. So, the procreated shape analysis was employed aiming at obtaining the mark of gait. On the other hand, [10] showed the essential frame for technology identification that views the aim according to the draw template of the human body. In addition, [11] examined the front and side views of the dynamic characteristics. They used the features of motion including that of arms, legs and of body shaking to identify the exact gait and improving the rate of recognition. Through this technique, [12] exercised also the appearance and the view.

Moreover, in the work of [13], the contour of binarization as a feature of using a dynamic of warping time was submitted to treat the existing changes in the speed that occur during the process of walking and strengthen the fault allowance in the original data. Additionally, [14] focused on using the external contour width for the binarized silhouette as a feature of image. They formed a model called HMM to discriminate the features as a dynamic of the walk. Furthermore, [15] also organized a HMM technique for recognition of gait. As the feature of motion, the descriptor pattern of local binary has been used by them. Consequently, [16] proposed interim template. It was used firstly for the representation of the appearance that based on action. The researchers utilized the images of motion energy and images of motion history to signify sequences of motion. Recently, new attempts are practiced to use the information on the depth silhouette as the feature of motion for recognition of gaits. So, [17] discussed a latest feature called the Volume of Pose Depth. This feature in particular, is based on the depth [2].

According to [18] and [11] charted the movement of leg in the human body within a model of pendulum that a part of model-based approach. This approach holds a pendulum motion and structure's models. Two interconnected pendulums were modeled the lower limb. Another attempt was

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for [19] included calibrating manually the rotation of thigh and curves, and extracting the angles' transformation as a feature. In contrast, [20] proposed a model based on joints that extracted from lower limbs of the lateral sequences of walk. So, to identify the gait recognition, [21] studied the effects of covariates including shoes wear, clothing, carriage of loads, and walking in speed.

In addition, several approaches have been applied to address the variations issue in the status of carrying. The spatio-temporal motion technique that based on characteristics, numerical and bodily parameters (STM-SPP), was among of them. Hence, [22] examined silhouette contour's form through adapting Procrustes analysis at double support part and Elliptic Fourier Descriptor within ten stages of a gait. A part-based EFD analysis is used to address the distortion shape due to the carrying conditions. The method of [23] exploited the main forms aiming at obtaining skeleton parameters through disintegrating of wavelet of energy image in a gait as well as fixing the moments for anatomical combination purposes and gait's behavioral characteristics. In order to extract silhouettes that are invariant to carrying conditions and lighting variations, thermal imaging is also used. Also, an algorithm of iterative local curve embedding is used in [24] to extract signatures of double helical.

3. PROPOSED METHOD

This proposed method consists of pre-processing, feature extraction and post-processing. Figure 1 shows the proposed method.

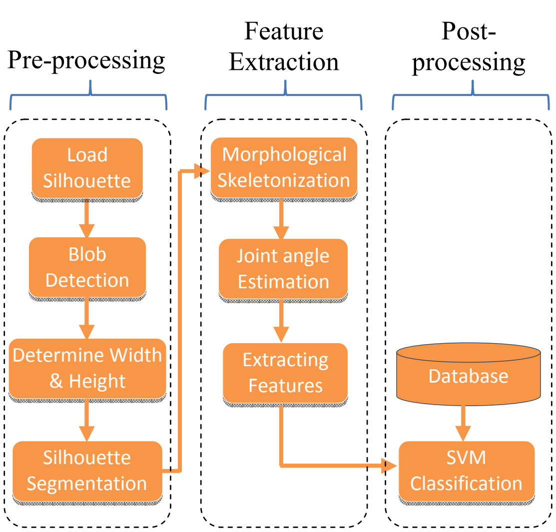

Figure 1: Work flow of our proposed method for human gait recognition.

3.1 Pre- Processing

This stage is considered significant to part and extract the specific region of interest (ROI) in silhouette input image. The ROI in the intended work is the silhouette areas.

3.1.1 Blob detection

Blob Analysis is also used to calculate statistics for labeled areas in a silhouette image. The regions return quantities such as the centroid, label matrix, and blob count and bounding box measurements. Thus, the detected pixels will be surrounded by the means of bounding boxes.

3.1.2 Height and width of Determination

Based on blob analysis the centroid and bounding box are identified. By using this identification, height and width of each silhouette are determined. Height and width are to be the main features in order to extract the silhouettes during their moving.

3.1.3 Silhouette Segmentation

In this paper, the human model is built in according to Figure 2 [25]. Both upper and lower torso motion angles are used. The gait is affected greatly by the motion angles, and they consider most influential in distinguishing the motion angles' capability. So, an articulated human model is assumed. So, Figure 2 (a) shows the model human that consists 11 segments of a body. In fact, ten joints are included in the human model, such as neck, waist, right shoulder, right elbow, left shoulder, and left elbow as Figure 2(b) shown in the below.

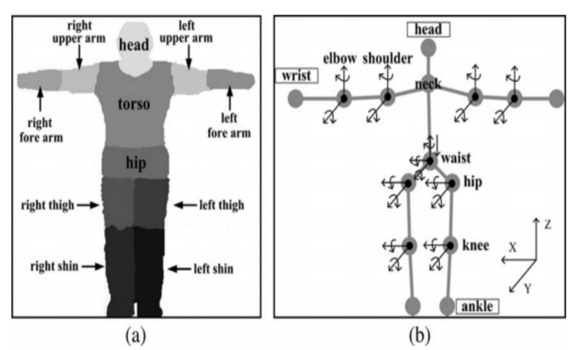

Figure 2: illustrates the Human model. (a) Segments of the Body. (b) Joints of human being and DOF.[25]

Furthermore, from the opinion of [26], the human silhouette is divided based on the centroid of the silhouette. The above and below parts of the centroid of the silhouette were divided in the horizontal direction with some ratios concerning head portion 19%, upper torso 20%, lower torso 20%, thigh portion 20% and calf portion 21% of total height. The vertical includes the front and back sections, except the head portion. Based on

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the above stated rations, a silhouette image is segmented to 6 areas and the joints were extracted. In this paper, the neck, waist, left and right knee, and left and right ankle joints are to be taken into consideration as Figure 3 illustrates.

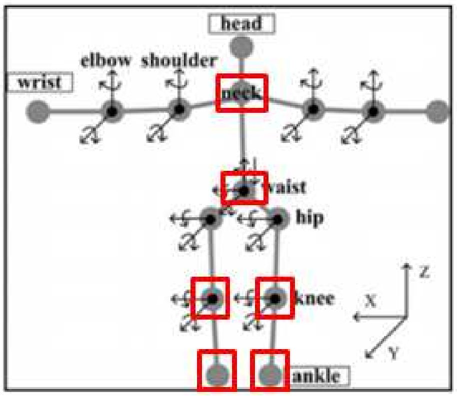

Figure 3: Six joint angles used in this paper.

3.2 Feature Extraction

In fact, the feature of extraction stage is consisted of three steps: skeletonization, joint angle estimation and extracting of features. This feature of extraction is considered the major step of this paper.

3.2.1 Skeletonization

Skeletonization provides an effective and compact representation for the image of an object by reducing its dimensionality to a “medial axis” or “skeleton” while the topologic and geometric properties of the object preserve. It also facilitates the efficient assessment of local object properties, such as scale, orientation, topology and etc. [27]. Although, the use of skeletonisation lies in the quantitative characterization of object morphology, it uses here as a compact representation for the object. In this paper, skeletonisation function in Matlab is used for the purpose of generating the skeleton image.

3.2.2 Joint angle estimation

Joint angle areas are extracted from the skeleton image based on segmented and distributed regions from the silhouette segmentation step. As mentioned above, these distributed areas include 6 regions segmentation as shown in Figure 4.

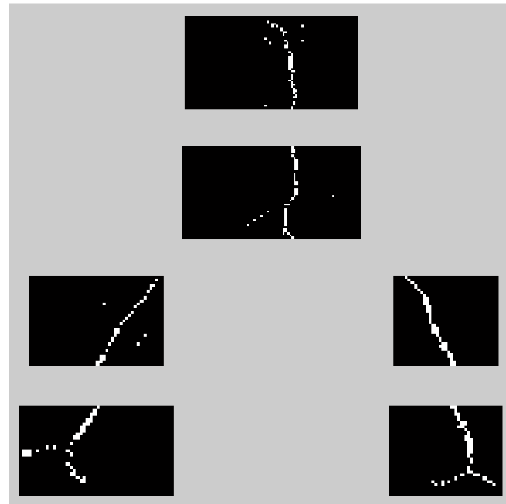

Figure 4: Six regions segmentation.

3.2.3 Extraction Features

In accordance with the resulted motion angles, the way to extract feature has become obvious. Some related work that including Fourier descriptor for [28] the purpose behind using the motion angles were focused on obtaining specific feature for such angles' motion. Though, the CCR that based on Fourier descriptor [28] is established to be limited. Similar to [2], as for the 2D database we select 50 persons randomly with 6 motion segments each. The angles of motion are extracted as vectors of angle pair as shown in Equation 1.

$$\left\{ \begin{array}{c} \theta_{neck} = \{(\theta_{neck})\}, \\ \theta_{waist} = \{(\theta_{waist})\}, \\ \theta_{knee} = \{(\theta_{knee\,1}, \theta_{knee\,2})\}, \\ \theta_{ankle} = \{(\theta_{thigh\,1}, \theta_{thigh\,1})\}, \\ Height, \\ Weight \end{array} \right\} \quad (1)$$

As shown in Equation 2, the Gabor filter is represented by a Gaussian that includes the s_x and s_y, x and y-axes variants respectively. These variants are modulated by a complex sinusoid and means of center frequencies U and V, x and y-axes respectively as shown in the following equation of [29]. Gabor filter selects this feature along with a particular direction under the main consideration. This reduction in the number of points for Radon Transform needs to be calculated. Even though Gabor filter includes less number of points, and the computation requires further time to reduce the entire speed.

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$$g(x,y) = \frac{1}{2\pi s_x s_y} exp\left[-\frac{1}{2}\left\{\left(\frac{x}{s_x}\right)^2 + \left(\frac{y}{s_y}\right)^2\right\} + 2\pi j(Ux + Vy)\right] \quad (2)$$

Where S_x , S_y is variances characterize the spatial extent along x and y-axes respectively. And U_x , V_y represent the particular 2-D frequency along x and y-axes respectively.

The Radon transform in the opinion of [30] is the image intensity projection that accompanies a radial line which oriented at exact angle. The radial coordinates are the values of the x'-axis, which is oriented at zero degree (θ) that opposes the clockwise from the side of x-axis. So, the center pixel of the image is considered the source of these axes. For example, the line integral of f(x,y) in the vertical direction is the projection of f(x,y) onto the x-axis; the line integral in the horizontal direction is the projection of f(x,y) onto the y axis. The Radon transform of a 2-D function f (x, y) is defined as Equation 3:

$$R(r,\theta)[f(x,y)] = \iint_{-\infty -\infty}^{\infty \infty} f(x,y)\,\delta(r - x cos\theta - y sin\theta)dxdy \quad (3)$$

In the case when r is the vertical distance, it could be originated from the original line, and θ is to match the angle that separates the line from the y-axis. Consequently, for the matter of identifying the trends' linear inside images, Radon transformation is to be applied. With this direction, Radon transform is in general distinguished by many variants. The projection's variance at such direction is considered maximum in the local area.

In short, Fourier, Radon and Gabor features for each joint angle area are extracted to estimate the joint angle. The joint angle estimation is performed on 6 regions. The feature vector is consisted of 6 angles, height and weight of silhouette. The previous Equation 1 illustrates the specific joint angle.

3.3 Post –Processing (classification)

3.3.1 Distance Measurement

It is significant to know that gait is represented by a feature histogram, so the distance of two gaits can be defined in according to the occurred similarity between two histograms. So, this similarity could be calculated by using several appropriate functions. In according to approach of [2], various distance measurements are used for similarity measurement. In this paper, a X^2 function is to be utilized to measure the similarity. X^2 function is also experienced for statistical test and evaluating the difference between two sets of data. We use here a symmetric approximation of X^2 as shown in Equation 4,

$$d_{x^2}(H1, H1') = \sum_I \frac{(H1(I) - H1'(I))^2}{H1(I) + H1'(I)} \quad (4)$$

Where d_{x^2} is the distance between two histograms $(H1, H1')$, $H1$ and H_1' denote to the two main corresponding histograms , I refers to the index of bins . So, when H_1 (I) and H_1' (I) are both equal to 0, d_{x^2} $(H_1 , H_1') = 0$.

3.3.2 SVM

In post-processing step, classification is performed to distinguish the human silhouette. For classification, Support Vector Machine (SVM) is considered in this paper. SVM classifier is proven to be superior in solving the histogram-based classification problem. The learning model (SVM) is shared the facts with algorithms through which data analyzes and patterns recognize. So, this model uses for dual rating. The undisclosed reason of SVM adopting is related to a kernel selection because the ordinary execution may cause by choosing improper kernel. Basically, the number of selected kernel is four. K_{poly} maintains its position in the polynomial nucleus, K_{RBF} uses for a Radial Basis Function (RBF), K_{sig} uses for the kernel of sigmoid, and the last one is K_{line} for the kernel of linear. As shown in the study of [2], K_{sig}, attains its utmost rate in the correct classification avarage (CCR). The K_{sig} distinguishes the perfect performance among other kernels. In this paper, the researcher uses K_{sig} for a kernel in SVM classification.

4. EXPERIMENT RESULTS

The 2D gait database that used in this work is related to Gait Database called CASIA, type B Dataset [35]. This type of Gait database was designed in 2005 and used widely in the most researches of gait recognition recently. They include 124 subjects and the subjects are filmed from 11different views. The angle that separate 2 adjacent observations is eighteen degree (18º), the angle's view is zero degree (0º), eighteen degree (18º), thirty six degree (36º), fifty four degree (54º), seventy two degree (72º), ninety degree (90º), one hundred and eight degree (108º), one hundred twenty six degree (126º), one hundred forty four degree (144º), one hundred and sixty two degree (162º) and one hundred and eighty degree (180º)

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from left to right. So, three variants including angle's view, status of clothing or and carrying emerged to be taken later into consideration separately. The captured sample is merely frames. In current paper, we employ the side view of frame and angle's view of ninety degree (90º) in the database.

In this experiment, CASIA Gait Database was the source of obtaining data. Currently, this database has become widely use and several publish papers adopted this dataset. For the purpose of comparison, the result of lateral view is used. Based on the walking status, an experiment is proposed. It is conducted on diverse data taken from normal walking or walking with carrying a coat or a bag. To measure the recognition rate, the percentage of correct classification rate is calculated by using the following Equation5,

$$CCR(\%) = S_c / S_t * 100 \quad (5)$$

Where S_c represent the number of correctly identified subjects in the Dataset and S_t represent the total number of subjects in the Dataset. Furthermore, K_{sig} and $D\chi 2$ are considered the calssification of kernel and distance measurement similarity in this paper.

In addition, the present experiment argues the way by which the results of recognition could be affected by clothes. In the prior types of work clothing, they used to be treated as a significant factor. Their influences can be reflected on the whole shape of body, therfore, some clothing's certain types have an effect on the way of a person's walk. In a study made by [21] a significant decreasing in performance from eighty seven degree (87%) to sixty degree (60%) was stated at the case persons wear a coat on their clothes in normal case. Accordingly, the evaluation of our method is to consider whether the intended process would be applicable or not within the sensitive clothes.

CASIA Gait Database and Dataset B include 3 categories of the date, such as data on normal walking or on walking with carrying a bag or a coat, and the total was of 124×10=1240 motion segments. So, the whole data were mixed together to evaluate the proposed method. Some previous work also had their attempts for solving the issue of clothes. Indeed, several methods were talk over the CASIA Gait database issue that relates to the main type of clothes.

In this regard, [2], the training of dataset is fixed to 60 motion segments in random case selected from the Gait Database. Accordingly, the paremeter of regularization (C) is set to 400. The testing data were the mixed data including the motion segments that chosen randomly from the normal walking data, from the on walking with a coat, or a bag. In the next step, the three motion of segments weighted against the entire dataset. Based on the expermental results, we achive to obtained 98.41 % of the recognition rate. The recognition rate was obtained from CCR which is calculated by Equaion 5. Ultimately, the proposed method was compared with other related works as shown in Table 1. The results were for [31], [32], [33], [34] and the methods were aquired from the study made by[2].

Table 1: illustrates the conducted comparison of recognition rate results of mix data between the proposed method in the research and others

Dataset	Liu & Wang [31]	Xu & Zhang [32]	Nagendraswamy [33]	Li & Chen [34]	Lu et al [2]	Our proposed method
CASIA datset B	83.00%	89.70%	91.50%	89.29%	98.16	98.41%

As shown in Table 1, the results show that our proposed method is work correctly within the mixing data. In contrast with other related techniques, this method reflects the most wanted results. As it is illustrated in Table 1, the average rate of recognition that attained by our system reaches 98.41% and the rate of recognition that accomplished by [2] reached 98.16% for the same data base. Experiments were tested on CASIA (B) to demonstrate that our method can attain a high-quality recognition performance.

Furthermore, Table 1 indicates the proposed method is not clothes sensitive as the recognition rate is high.

5. CONCLUSION

In the current paper, a method of gait recognition on the bases of the joint angle estimation for person's motion is proposed. As vectors of pair angles, the motion angles are extracted. In addition, the feature of histograms is stated for identifying gait recognition. The experiments on 2D video gait database are conducted to assess the efficiency of the applicable method. The presented consequences are based on

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the correct classification rate and the proposed method effectiveness within 2D database. Furthermore, comparisons to compare the recognition rate results are also conducted. As show in the comparison tables, the research's proposed method is considered effective in comparison with other related methods. In future, the research is to try to compare this method with various databases. The upcoming algorithm of the research, the drawback of discontinuity present in the silhouettes should be eliminated.

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