Gait Feature Extraction and Recognition in Biometric System

Syed Nafis Syyed Ngah Ismail[1], Muhammad Imran Ahmad[1], Said Amirul Anwar[1], Mohd Nazrin Md Isa[2], Ruzelita Ngadiran[1]
[1]*School of Computer and Communication Engineering,*
[2]*School of Microelectronic Engineering,*
Universiti Malaysia Perlis, Kampus Pauh Putra, 02600, Perlis.
m.imran@unimap.edu.my

***Abstract*—This research focus on the development an automatic human identification system using gait sequence images. Human identification is widely used in computer vision applications such as surveillance system, criminal investigations and human-computer interaction. Gait sequence image is a non-stationary data and can be modelled using a statistical learning technique. The propose technique consists of three different stages. The pre-processing stage computes the average silhouette images to capture the important information and get a better representation for gait silhouette data. Then a principle component analysis (PCA) technique is applied on the average silhouette to extract the important gait features and reduce a dimension of gait data. A linear projection method used in this stage is able to reduce redundant features and remove noise data from the gait image. Furthermore, this approach will increase a discrimination power in the feature space when dealing with low frequency information. Low dimensional feature distribution in the feature space is assumed Gaussian, thus the Euclidean distance classifier can be used in the classification stage. The propose algorithm is a model-free based which uses gait silhouette features for the compact gait image representation and a linear feature reduction technique to remove redundant and noise information. The proposed algorithm has been tested using a benchmark CASIA datasets. The experimental results show that the best recognition rate is 90%.**

Index Terms*—*Biometric; Gait Recognition; Information Fusion.

I. INTRODUCTION

In last decade, there has been an issue to effectively identifying and classifying an individual. Since then, all researcher around the world put their effort to enhance biometric recognition for the benefit of recognition capabilities. There are somehow have many type recognition for biometric which is face, palm, iris, gait and so on.

Human often used faces to recognize an individuals. Until now, advancement in computing capabilities now enables similar recognition but with different method. One of pattern recognition task that is effectively used on human is gait. Human walk and move with different way. Based on the same concept as human and advancement in computing a system has been design to help human in our life known as gait recognition system.

Biometrics is a branch of technology that depends on automated methods to verify and identify humans. Biometric identification must be an automated process. Using manual feature extraction is undesirable and time consuming because of the large size of data being processed to produce a biometric template. Two main types of biometric characteristics, namely, physiological and behavioural, are used in biometric identification methods. Physiological characteristics are based on direct measurement of human body parts. The most common types of measures are related to the face, fingerprint, iris, palm print, and DNA. Behavioural characteristics are based on extracting the characteristics of actions performed by humans. This type of biometrics uses an indication to measure the characteristics of human motion and time as a metric. The types of behavioural measure include gait, voice, keystroke, and speech [1].

Gait recognition has becomes researchers attention in the past years as one of the promising biometric identification and verification. One of the advantage of gait is its capability to be captured even from far distance by video camera which is suitable to be used in forensic applications, security and surveillance.

Gait in other word is a style of walking of an individual. Frequently, in surveillance system, face and iris information quite difficult to get as the resolution needed for recognition is much higher than gait. Besides, it is vital for face and iris to have a good quality image for recognition purposed. Thus, gait is much better option for surveillance application than other biometric recognition because gait only required a moving individual for recognition purpose without having a high quality image as the main requirement.

Somehow there also aspect that should considered important. Human have different height and width for each individual. Gait recognition system somehow need to be precise in gathering information that include height and width of an individual [2]. In addition, each individual have different way of walk in their life. This can be clarify by different position, velocity, shape, texture, and colour of a normal walking people. For a normal walk, gait sequences are repetitive and show an individual behaviour. As gait databases properly to grow in size, it is imaginable that identifying and recognizing a person only by gait may become more difficult. However, gait still one of biometric that are capable to help narrow down the search to a smaller set of candidates.

A. Model Based Approach

This model fits a person in each frame of the walking sequence with constraints on the body model of the walking sequence [3]. The model-based approach is robust to occlusion and noise, but the process of this model requires high computational cost and time [4]. The model-based approach concerns identification using an underlying mathematical construct that represents discriminatory gait characteristics which is static or dynamic with a set of parameters, as well as logical and quantitative relationships among them. Unlike model-based approaches, holistic solutions operate directly on the gait sequences without assuming any specific model for the walking human.

Model-based approaches have a cluster of static or dynamic body parameters through modelling or tracking body components likes limbs, legs, arms and thighs [5]. From these model parameters are then produced gait signatures used for identification and recognition of an individual. Model-based approaches proven that it is view-invariant and scale-independent. These advantages are significant for practical applications, because it is unlikely that reference sequences and test sequences are taken from the same viewpoint [6]. Besides that, model-based approach are very sensitive to quality standard of image of gait sequences. Thus, high quality images of gait sequences are needed to get high accuracy result. Addition, it have some other disadvantage because of its large computation and relatively high time cost due to its parameter calculations.

Some of the method is separately model the human body parts. In Wang et al [7] project, in modelling human body, fourteen rigid parts has form by connecting to each other at the joint. Forty eight degrees of freedoms for each model. Joint-angle trajectories signals or tracking result are subjected like gait dynamic for verification and identification. Procrustes shape analysis are using to get the static information of body based on the change of moving silhouettes. Then, both information of static and dynamic can be combinative or independently employed to increase the recognition rate. More recently, Boulgouris and Chi [8] human body are separate into different parts or components and then form a common distance metric by combining the result get from every different human body parts. Study of each part’s contributions in recognition performance proof that the higher the contribution of parts the higher the recognition rate that will achieve. In addition, Li et al. [9] has seven different parts of gait cycle which is consist of divided average silhouettes and impact of each part of gait cycle is summarized for gait recognition purposed.

In the beginning, Cunado et al. [10] has invent a model to be used as two inter-connected pendulums for lower limbs and image for lower limbs is extracting using Hough transform method. After that, evidence gathering then used for extracting gait signatures. Zhang et al. [11] in his work has used a five-link biped technique for movement of human model in extracting the features. The physical structure and movement limitation of human body can be effectively represent by using the base-to-height ratio vector combine with the relative height vector. This approach more effective to different cloth of each subject wore. Besides that, it is difficult to get the exact arm positions as it is obtained of five trapezoids but without arms. In Dockstader et al. [12] , proposed a hierarchical model that employed a set of thick lines joined at a single point. The legs and a periodic, pendulum motion model was represent at a single point for gait pattern descriptions.

Model-based method is suitable for tracking features and is remarkably robust to view-invariant representation and scale independent. Thus, it is commonly used for feature tracking which can be extracted the image position of features from separated region. Feature tracking estimates the posture of gait by finding features observed images [13]. It needs parameters which are used for identification of an individual. Wachter [14] by employed the elliptical cone model, thus, can presented the results to show the contours of each body parts in detail. Somehow, the disadvantages of this approach however it is only tracks the poses of human body by using only model axes which is corresponded with image coordinates. It also impact an object for image sequences of posture information to cannot reconstruct again.

B. Model Free Based Approach

This method is the most popular approach used in gait recognition techniques. It is based on analysing human motion and extracting distinct features. The recognition process in this approach is based on subject detection, silhouette extraction, and feature extraction and classification. After detecting the human motion captured by the sensor (camera), background subtraction is performed on the detected human gait, which is followed by feature extraction on the detected gait features. After feature extraction, dimensionality reduction is performed because the extracted features have high dimensionality information. Finally, a classification technique is performed on the reduced dimension gait features.

Model free-based algorithms extract statistical information such as gait features of silhouettes (e.g., width, contours, projections, and motion patterns). This approach attempts to derive data from the human walking sequence that is similar for each subject but different for different subjects. This technique is also insensitive to the quality of silhouettes and has the advantage of low computational cost compared with model-based approaches [15]. However, these algorithms are not robust to viewpoints and scale. The model free-based approach is used in the present study as a method to develop the proposed gait recognition algorithm.

Figure 2 shows the three main model free-based methods used to design gait recognition algorithms: (1) direct method, (2) similarity of the temporal sequence method, and (3) state space model method [16]. The direct method is based on frames extracted from a sequence of gait features. The state space model method is based on the similarity of shapes and shape-appearing probabilities. The similarity of a temporal sequence method is ignored by the direct method. The direct method consists of three basic techniques: (1) statistical, (2) neural network, and (3) hybrid. The present study is based on direct statistical methods to develop the proposed algorithm.

It also focuses on silhouette shape and the dynamic information, which is used for pattern matching. Dynamic information is collected by using temporal alignment techniques [17]. Khalid et al. [18] used height of the outermost counter of the silhouette whereby the right most pixel and the left most pixel of each row of the normalized silhouette belongs to the outermost counter. This method is feasible and low cost. Other than that, this method ignores the space between the two legs. Moreover, imperfect segmentation gives the shadow of the legs which is good for recognition. Dong Xu et al. [17] proposed a new Patch Distribution Feature PDF. In this work, Gait Energy Image (GEI) was presented as a set of local augmented Gabor feature in concatenation with Gabor features extracted from various scales and orientations combine with 2D x-y coordinate.

Model-free approaches aims on shape of silhouettes or the whole movement of human bodies, rather than modelling the whole human body or any part of the body [5]. Different from model based approach, model free approach are insensitive to the image quality of silhouette. It also have the advantage of low computational costs but usually not robust to viewpoints and scale.

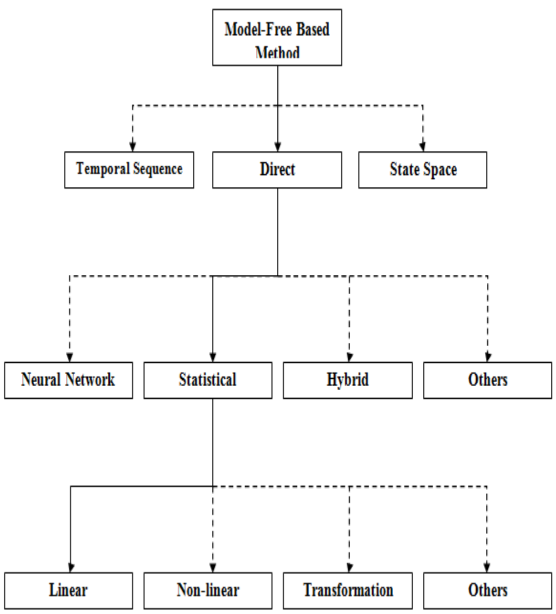

Figure 1: Model-Free Based Approach

Some other algorithms pay attention to analyzing the whole shape of silhouettes. Wang et al. [19] applied the Procrustes shape analysis to silhouette shapes and extract a Procrustes mean shape from a sequence of silhouettes as gait signature. To get a template from gait sequences, Boulgouris and Chi [20] perform Radon Transform on the binary silhouettes. Radon template coefficient was extracted by using Linear discriminate analysis (LDA) and subspace projection that is used to construct feature vector. Murase and Sakai [21] described an approach that using the parametric eigenspace representation in order to reduce computational requirement and improve the robustness.

Meanwhile, the outer contour of silhouette often used to extract gait signatures, too. Wang et al. [22] used the distance between pixels along the contour and the shape centroid to unwrap the two-dimensional (2D) contour of silhouette to a one-dimensional (1D) signal. Apparently, A. Kale et al. [23] improvised the width information because of insufficient for represent the human walking by combining the width of outer contour silhouette and the entire silhouette as gait signature. Hayfron-Acquah et al. [24] applied an approach based on the symmetry analysis, whereby Soble operator was used to obtain an edgemap on the gait silhouettes and the Generalized Symmetry Operator was then applied to give the symmetry map. Gait signature was computed from the average of all the symmetry maps in a gait silhouette sequence.

Other algorithms focused on the silhouette sequences for recognition. Sarkar et al. [25] approached the baseline algorithm, whereby scaled and aligned silhouettes sequence were used as gait signature directly. After all, the performance of the algorithm was quite satisfying despite the approach seemed straight forward. Also same as Sarkar's work, Bobick and Davis [26] generated the motion-energy image (MEI) and motion-history image (MHI) from the silhouette sequences to represent human walking. MEI is a binary image that represented by the motion appeared in an image sequence while MHI, which is created from MEIs and was a vector-image from the vector value represented the recency of motion. Meanwhile, Han and Bhanu [27] applied the idea of MEI to determine the gait energy image (GEI) to reflect the changes of silhouette shape and gait period. Moreover, GEI was comparatively robust to noise by averaging images of a gait cycle. However, it lost the dynamical variation between successive frames. Chen et al. [28] employed the frame difference energy image to solve the problem of silhouette incompleteness. In Xue et al. [29] the wavelet decomposition of GEI was applied to infrared gait recognition. The experimental results shows the robustness of the covariates of holding a ball and loading packages. Lam et al. [30] proposed gait flow image (GFI) for gait representation, which was determined by calculating the optical flow field.

To some degree, gait sequence is in accordance with the characteristics of the Hidden Markov Model (HMM). Kale et al. [2] applied HMM to collect the information in gait sequence and recognise individuals. Chen et al [31] employed Factorial HMM as feature-level fusion scheme to merge different gait features, where the results from the Parallel HMM decision level fusion scheme was compared.

II. RELATED WORK

Human silhouette image quality play a biggest role on gait recognition performance as the better the quality of human silhouette the higher performance of recognition. Changhong et al [28] proposed that a robust dynamic gait representation scheme, frame difference energy image (FDEI), to conceal the influence of silhouette imperfection or in other word called incompleteness. Firstly, gait cycle is divided into some amount of cluster than all the noise of average image of each cluster was remove and form the dominant energy image. All corresponding cluster's DEI was adding to frame of FDEI representation. This representation scheme was tested on the CMU MoBo gait database and CASIA gait database. The frieze and wavelet features are adopted and employed Hidden Markov Model (HMM) for recognition.

Good extraction of gait features from each sequence of image and their recognition are two essential issues for gait recognition. In this journal write by Rong Zhang et al. [11] proposed a method based on model-based approach to gait recognition by operating a five-link biped at human model. At first, Metropolis-Hasting method was employed in extracting the gait features from image. Frequencies of feature trajectories were used for estimation of Hidden Markov Model (HMM) training. It is more advantages when subject wore different type of clothes because this approach was robust to every each different types of clothes. Feature extraction step of model based gait is insensitive to noise, clutter background or moving background. The size of data required for recognition by using model-based approach is much smaller instead of model-free approach. They have used both USF Gait Challenge data set and CMU MoBo data set for recognition.

Rasyid et al. [32] proposed a method for recognition of gait by suppressing and using gait fluctuations. Temporal fluctuations caused by inconsistent phasing between a matching pair of gait image sequence has degrades the performance of gait recognition. In this paper, they generated a phase-normalized gait image sequence using equal phase intervals to get rid of temporal fluctuations. On the other hand, they extracted phase fluctuations become temporal fluctuations while gait fluctuation image and trajectory fluctuations as spatial fluctuations. Those temporal fluctuation then combined with the matching score by using phase-normalized image sequence. In score level fusion framework, phase-normalized image sequence acts as an additional matching scores while in score-normalization framework, it worked as quality measures.

Guoying et al. [33] worked on fractal scale. It was used to describe and automatically recognize gait. It is theoretically based on wavelet analysis, depicted the self-similarity of signals and improves the flexibility of wavelet moments. Fractal scale provide translation, scale, rotation invariant and has anti-noise and occlusion handling performance. Besides that, fractal scale decreased the computation complexity by introducing the Mallat algorithm of wavelet. From this work, it shown that fractal scale has simple computation and it is an efficient descriptor for gait recognition.

Ju Han and Bir Bhanu [27] proposed a new spatio-temporal gait representation, called Gait Energy Image (GEI). GEI was applied to categorized human walking properties for gait recognition. In addition, they proposed a novel approach for human recognition by combining statistical gait features from real and synthetic templates in order to solve the problem of lacking of training templates. The real templates computed from training silhouette sequences, while the synthetic templates generated from training sequences by simulating silhouette distortion. A statistical approach was used for learning effective features from real and synthetic templates. After that, the proposed GEI-based gait recognition approach was compared with other gait recognition approaches on USF HumanID Database. For the experimental results, the proposed GEI proved it is an effective and efficient gait representation for individual recognition, and the proposed work achieves highly competitive performance with respect to the other gait recognition approaches.

Fusion-based approaches

Normally, recognising a person does not depend on only a single gait feature for human vision perception system to works, instead there are so many properties of the person that will work as alternatives. To this end, combining or fusing multi-source information can be a good strategy to improve the recognition performance. These include feature-level fusion and decision-level fusion, respectively, and relevant techniques are discussed as follows.

Besides that, there also fusion of dynamic and static body biometrics. Liang et al. [7] proposed that a gait recognition system and algorithm based on fusion of dynamic and static body biometrics. For each gait cycles, every movement of body part that has been segmented into moving silhouettes are portray as an associated sequence of complex vector configurations. It is then analysed by using the Procrustes shape analysis method. This method can get a static information of body. In addition, a model-based approach is work as Condensation framework which is by track the subject walking movement and also to retrieve every joint angle trajectories of both lower limbs. This process is called dynamic information of gait. After that, information of both dynamic and static are then used for recognition process by using the nearest exemplar classifier. Since various types of gait features are normally fused to increase the recognition performance, combining multiple features is an innate way for gait-based recognition. The results shows that the performance and efficiency of fusion-based approach was better instead of single type of gait features. Meanwhile, combining results from multiple biometric characteristics for decision-level fusion has gradually attracted more and more attention. Besides that, two factors were considered which are the view angle and the subject to camera distance. All achievement and success of these approaches proved that multi-modal biometric recognition has become high potential research topic.

III. EXPERIMENTAL ANALYSIS

The goal of this experiment is to validate the proposed gait recognition method using non-stationary gait motion data. Gait data provided by CASIA are used in all experiments. Several analyses have been conducted using the CASIA gait dataset A to validate the proposed algorithms. The CASIA gait dataset A contains gait silhouette data on 20 subjects, where each subject has 12 sequences of gait silhouette images. Four gait silhouette images have a sequence of different viewing angles, such as 90 degrees, 45 degrees, 0 degree, and parallel, from the camera. Each gait silhouette sequence has a different number of silhouette frames with a 352 × 240 size because of the variation of subject walking speeds ranging from 37 to 127 frames. The gait silhouette data of 10 subjects are used in this experiment from the CASIA gait dataset A for both training and testing. The gait silhouette sequences for each subject with the side view (0 degree viewing angle) of left-to-right movement direction are applied to the proposed algorithm. Given that each subject has two different gait silhouette sequences for the same viewing angle and movement direction, the first gait silhouette sequence is used for training, whereas the other is used for testing. Different representation methods with different frame sizes, number of silhouette frames for each gait silhouette sequence, and number of PCA coefficients have been applied in this experiment. Several parameters are examined to determine the best performance that can be achieved in terms of recognition rates.

The performance of this method is measured in terms of identification rates as shown in Figure 2. The best identification rate achieved is 90% using an average silhouette method which calculates the mean of all gait silhouette images so it can preserve all important information. The row concatenation and column stacking provide lower results, which are 65% and 70% of recognition rates. Row concatenation and column stacking methods produce a lower results because of the fewer gait features when dealing with a high-dimensional 1D feature vector.

Gait silhouette data consist of multiple silhouette sequences where each silhouette sequence contains several silhouette frames. The extracted features from silhouette frames are used as training or testing gait patterns. The silhouette frame size and number of frames in each silhouette sequence determine the amount of information in the training phase as shown in the analysis in Figure 3 and Figure 4. By using different silhouette frame size different amounts of gait features can be extracted from the gait data. The best recognition rates can be achieved by using 160x160 frame size when the features are extracted using average silhouette. Number of silhouette frames also effected the performance of the system as shown in Figure 4. The best number of frames is 60 in order to achieved 90% recognition rates.

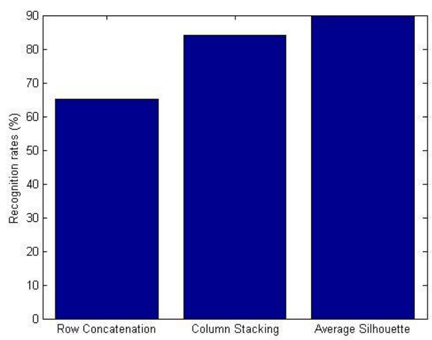

Figure 2: Comparison of different feature extraction method based on the recognition rates.

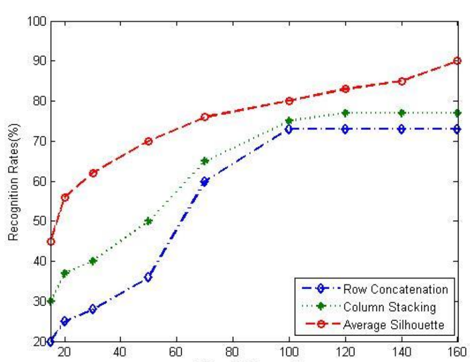

Figure 3: Analysis of different silhouette frame size

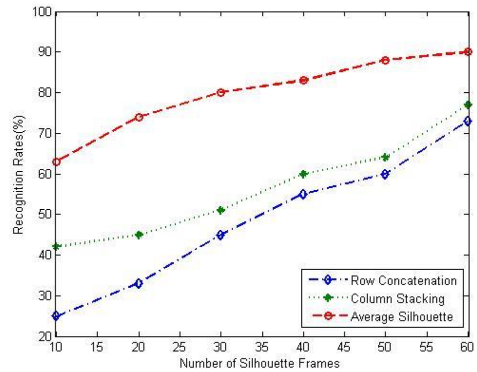

Figure 4: Analysis of different number of silhouette frames

IV. CONCLUSION

Gait is a behavioural biometric trait that can be used as an effective biometric feature for human identification. A model free-based human identification method using the gait recognition algorithm is proposed in this paper. The efficiency of the proposed algorithm for human identification is tested using the CASIA gait dataset. Experimental results show that the proposed method is convincing and stimulates high recognition performance when tested using the CASIA gait database, with 50 gait silhouette frames for each gait silhouette sequence and a 100 × 70 frame size. The best performance of the proposed method is a 90% recognition rate. The identification rate of the proposed algorithm achieves superior performance using the Euclidean distance classifier with fewer PCA coefficients used in a feature space.

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