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GAIT RECOGNITION FOR HUMAN IDENTIFICATION USING HIGH ORDER SHAPE CONFIGURATION

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ABSTRACT

This paper put forward Different from gait classification which classifies human motion into categories, such as walking, running, and jumping, gait recognition, also called gait-based human identification, is a relatively new research direction in biometrics. It aims to discriminate individuals by the way they walk. In comparison with other first-generation biometric features such as fingerprint and iris, gait has the advantage of being unobtrusive, i.e., it requires no subject. Human identification at a distance has recently gained growing interest from computer vision researchers. Gait recognition aims essentially to address this problem by identifying people based on the way they walk. In this paper, a simple but efficient gait recognition algorithm using Higher Order Shape Configuration Gait has been known as an effective biometric feature to identify a person at a distance. However, variation of walking speeds may lead to significant changes to human walking patterns. It causes many difficulties for gait recognition. A comprehensive analysis has been carried out in this paper to identify such effects. Based on the analysis, Procrustes shape analysis is adopted for gait signature description and relevant similarity measurement.

Key words: Human Motion Analysis, Biometrics, Principle Component Analysis, Differential Composition Model (DCM), Gait Recognition, High Order Derivative, Human Identification, Procrustes Shape Analysis (PSA), Walking Speed Variation.

I. INTRODUCTION

In a real-world environment, there are various factors significantly affecting human gait, including dressing different clothes, walking while carrying different objects, walking on different surfaces, walking with different shoes, walking under variable speeds, and walking while being observed from arbitrary views [2]. Among these factors, speed change has been regarded as one of most commonly seen challenging factors. The change of walking speed can significantly change the gait shape description. Human identification at a distance has recently gained growing interest from computer vision researchers. Gait recognition aims essentially to address this problem by identifying people based on the way they walk. In this paper, a simple but efficient gait recognition algorithm using high order shape configuration. For each image sequence, a background subtraction algorithm and a simple correspondence procedure are first used to segment and track the moving silhouettes of a walking figure. Then, eigenspace transformation based on Principal Component Analysis (PCA) is applied to time-varying distance signals derived from a sequence of silhouette images to reduce the dimensionality of the input feature space. Supervised pattern classification techniques are finally performed in the lower-dimensional eigenspace for recognition. This method implicitly captures the structural and transitional characteristics of gait. Extensive experimental results on outdoor image sequences demonstrate that the proposed algorithm has an encouraging recognition performance with relatively low computational cost. This interest is strongly driven by the need for automated person identification systems for visual surveillance and monitoring applications in security-sensitive environments such as banks, parking lots, and airports. VISUAL analysis of human motion [17], [25] attempts to detect, track, and identify people, and, more generally, to understand human behaviors from image sequences involving humans. Biometrics is a technology that makes use of the physiological or behavioral characteristics to authenticate the identities of people [18]. An ongoing research project, the Human ID program [1] initialized by DARPA(Defense Advanced Research Project Agency), aims to develop a full range of multimode surveillance technologies for successfully detecting, classifying, and identifying humans to enhance the protection of facilities from terrorist attacks. Its focus is on dynamic face recognition and recognition from body dynamics including gait. In recent years, several methods [4]–[9] have been proposed for cross-speed gait recognition from different perspectives. Based on their published results, it is observed that they can sort out the problem to some extent, particularly when the speed changes are small. However, it is still challenging to them when the speed changes are significant. The proposed method will tackle this problem as one of the core research objectives in this paper. To demonstrate the performance improvements by the proposed method, the relevant comparisons have been conducted in this paper.

II. RELATED WORK

In this paper, we propose a novel PSA-based method for speed-invariant gait recognition. It has the following significant points, which are different from the traditional PSA framework [10]–[12], [16]–[21]. First, prior knowledge of human shape structure is embedded in the resampling process to more precisely address the point correspondences. Three key positions of human body (i.e., the head and feet) are automatically detected and adopted as the reference points for the resampling. This assumption is reasonable for gait shape analysis since they are visible normally for standing posture under any speed and view. Second, to describe gait shape, we propose the HSC to replace the traditional CSC in the PSA scheme, which is not efficient to handle the speed change problem. HSC describes gait shape using high order information of the shape boundary such as tangent and curvature. Such information is consistent to describe gait shape regardless of global appearance change caused by speed change. We apply the derivatives [22]. Gait includes both the body appearance and the dynamics of human walking motion [34]. Intuitively, recognizing people by gait depends greatly on how the silhouette shape of an individual changes over time in an image sequence. So, we may consider gait motion to be composed of a sequence of static body poses and

Expect that some distinguishable signatures with respect to those static body poses can be extracted and used for recognition by considering temporal variations of those observations. Also, eigenspace transformation based on PCA has actually been demonstrated to be a potent metric in face recognition (i.e., eigenface) and gait analysis [6], [7], [11], [31]. Based on these observations, this paper proposes a silhouette analysis-based gait recognition algorithm using the traditional PCA. The algorithm implicitly captures the structural and transitional characteristics of gait. Third, in order to handle the large speed change, we propose the DCM, which

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decomposes gait shape boundary into segments. Such segmentation reflects various efforts caused by speed changes on different body parts. Each segment is assigned a weight to differentiate each other. Fisher discriminate is used to calculate the weight values. Then, the final similarity measurement between any two gaits is a weighted sum of distance of each corresponding pair of boundary segments. Current studies on cross-speed gait recognition fall into two categories: 1) identifying speed-invariant gait features, and 2) transforming gait features under various walking speeds onto a common walking speed. Some interesting studies in the first category are briefed below. Liu *et al.* [4] developed an hidden Markov model (HMM)-based time-normalized gait feature. Similarity between two normalized gait features was measured using a sum of shape distances corresponding to gait stances in linear discriminate analysis gait dynamics, which is based on a population-based generic walking model, has shown its effectiveness to compensate the hard covariates caused by the walking speed change. Tan *et al.* [5] used eight kinds of projective features to describe human gait, and PCA was applied for reduction of raw gait feature dimension. Mahalanobis distance was used to measure gait similarity. Projective normalization was used to improve the robustness of projective frieze patterns against speed variation. Kusakunniran *et al.* [6] applied a partial local binary patterns (LBP) concept on gait energy images and proposed adaptive weighting techniques to discriminate significant bits of partial LBP in gait features.

III. PSA-BASED GAIT RECOGNITION:

PSA [10], [20], [21] is a process of performing shape preserving Euclidean transformation on a set of shapes. It is able to achieve similarity measurement between two sets of shapes by properly superimposing. This property is useful for gait recognition. During superimposition, the positions and them sizes of gait shapes are adjusted by proper translation, rotation, and scaling. The core idea of PSA is to find the best way to superimpose one shape onto another shape, by minimizing the Euclidean distance of their shape configurations ($Z1$ and $Z2$) [21] as

$$\min_{\alpha,\beta} \left\| Z1 - \alpha 1k - \beta Z2 \right\|^2, \qquad \beta = |\beta|\, e^{j\angle\beta} \tag{1}$$

Where $\alpha 1k$ represents translation and $|\beta|$ and $\angle\beta$ represent scaling and rotation of $Z2$, respectively. To simplify the discussion, we consider an easy case where two shapes in (1) have been registered at their centroids, i.e., translation can be ignored. The solution of (1) can be obtained [21] as

$$\alpha = 0,\ \beta = \frac{|Z_1 * Z_2|^2}{\| Z_2 \|^2} \tag{2}$$

Where the superscript $*$ represents a complex conjugation transpose. The β presents the similarity between two shape configurations. Therefore, in the framework of PSA, Procrustes distance (PD) dP ($Z1$, $Z2$) is used to quantify the dissimilarity of two shape configurations as [20], [21]

$$\begin{aligned} dp(Z_1, Z_2) &= 1 - \arg\min \| Z1 - \beta Z_2 \|^2 \\ &= 1 - \frac{\| Z_1 * Z_2 \|^2}{\| Z_2 \|^2 \| Z_2 \|^2} \end{aligned} \tag{3}$$

where the β has been normalized as a value between 0 and 1.In this paper, PSA is employed for gait recognition. According to our research, PSA is helpful for analyzing gait shapes, which may be inconsistent due to several factors such as:1) various poses and sizes throughout a walking cycle and/or a camera's viewpoint; 2) inconsistency of individual walking patterns; and 3) change of walking patterns caused by the change of walking speed. In this research paper, we will show that PSA can tolerate these inconsistencies after additional efforts proposed in this paper. First of all, in this section, the existing PSA adopted for gait recognition is introduced in order to demonstrate the challenges of this research paper.

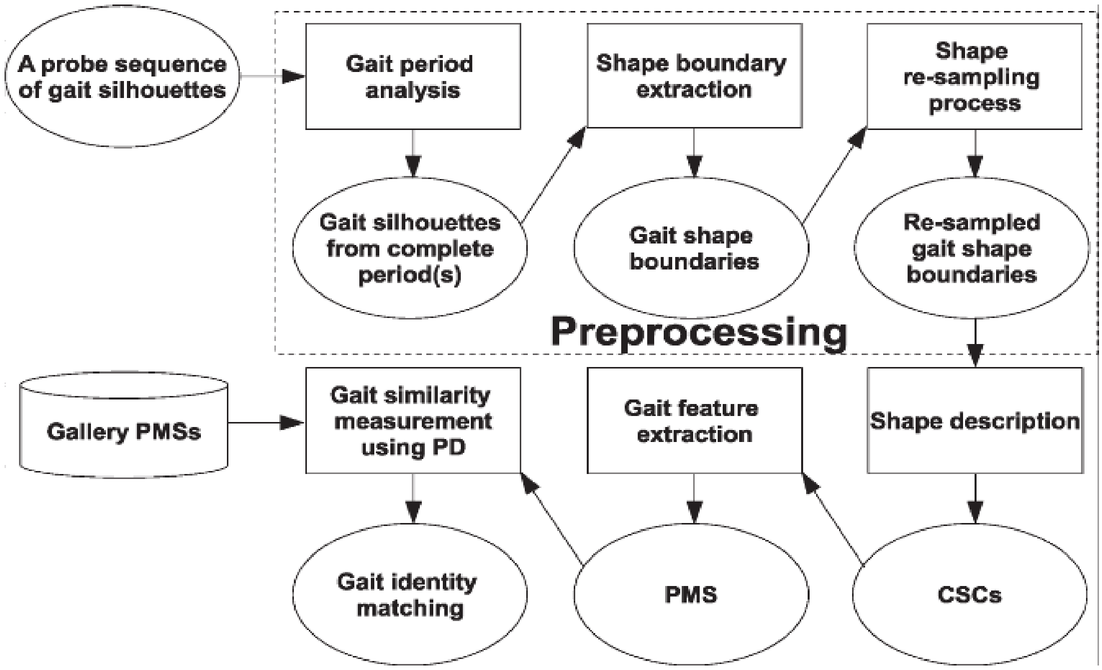

Fig. 1. Framework of PSA-Based Gait Recognition

Model-based approaches [28], [4], [8], [12], [14], [19], [32] aim to explicitly model human body or motion, and they usually perform model matching in each frame of a walking sequence so that the parameters such as trajectories are measured on the model. An early such attempt [4] modeled gait an articulated pendulum and used the dynamic Hough transform to extract the line representing the thigh in each frame. Fourier analysis was performed on the inclination data of the thigh and phase-weighted magnitude spectra formed gait signatures for recognition. Johnson and Bobick [14] used activity-specific static body parameters for gait recognition without directly analyzing gait dynamics. Yam et al. [19] first tried the running action of gait to recognize people as well as walking. Later, they further explored the intimate relationship between walking and running that was expressed as a mapping based on the idea of phase modulation [28]. Recovery from a walking video is still limited allowing for current imperfect vision techniques (e.g., tracking and localizing human body accurately in 2D or 3D space has been a long-term challenging and unsolved problem). Further, the computational cost of model-based methods is relatively high.3D space has been a long-term challenging and unsolved problem). Further, the computational cost of model-based methods is relatively high.

IV. PURPOSE AND CONTRIBUTION OF THIS WORK:

Gait has been known as an effective biometric feature to identify a person at a distance. However, variation of walking speeds may lead to significant changes to human walking patterns. It causes many difficulties for gait recognition. A comprehensive analysis has been carried out in this paper to identify such effects. Based on the analysis, Procrustes shape analysis is adopted for gait signature description and relevant similarity measurement. To tackle the challenges raised by speed change, this paper proposes a higher order shape configuration for gait shape description, which deliberately conserves discriminative information in the gait signatures and is still able to tolerate the varying walking speed. Instead of simply measuring the similarity between two gaits by treating them as two unified objects, a differential composition model (DCM) is constructed. The DCM differentiates the different effects caused by walking speed changes on various human body parts. In the meantime, it also balances well the different discriminabilities of each body part on the overall gait similarity measurements. In this model, the Fisher discriminant ratio is adopted to calculate weights for each body part.

V. FEATURE EXTRACTION

Before training and recognition, each image sequence including a walking figure is converted into an associated Temporal sequence of distance signals at the preprocessing stage.

VI: HUMAN DETECTION AND TRACTING

Human detection and tracking is the first step to gait analysis. Although it is not a main part of our work, in contrast to gait signature extraction and recognition, we still give a detailed introduction for completeness. To extract and track moving silhouettes of a walking figure from the background image in each frame, the change detection and tracking algorithm is adopted which is based on background subtraction and silhouette correlation. The main assumption made here is that the camera is static, and the only moving object in video sequences is the walker. Although this integrated method basically performs well on our data set, it should be noted that robust motion detection in unconstrained environments is an unsolved problem for current vision techniques because it concerns a number of difficult issues such as shadows and motion clutter. A new gait database, called the NLPR database, is established for our experiments. A digital camera (Panasonic NV-DX100EN) fixed on a tripod is used to capture gait sequences on two different days in an outdoor environment. All subjects walk along a straight-line path at free cadences in three different views with respect to the image plane, namely, laterally (0_), obliquely (45_), and frontally (90_). The resulting NLPR database includes20 subjects and four sequences for each viewing angle per subject. For instance, when the subject is walking laterally to the camera, the direction of walking is from left to right for two of the four sequences, and from right to left for the remaining. The database therefore includes a total of 240 gait sequences (20 _ 4 _ 3). These sequence images with 24-bitfull color are captured at a rate of 25 frames per second and the original resolution is 352 _ 240. The length of each image sequence varies with the pace of the walker, but the average is about 90 frames. To the best of our knowledge, our database is probably one of the concurrent gait databases available in the public domain, which is reasonably sized.

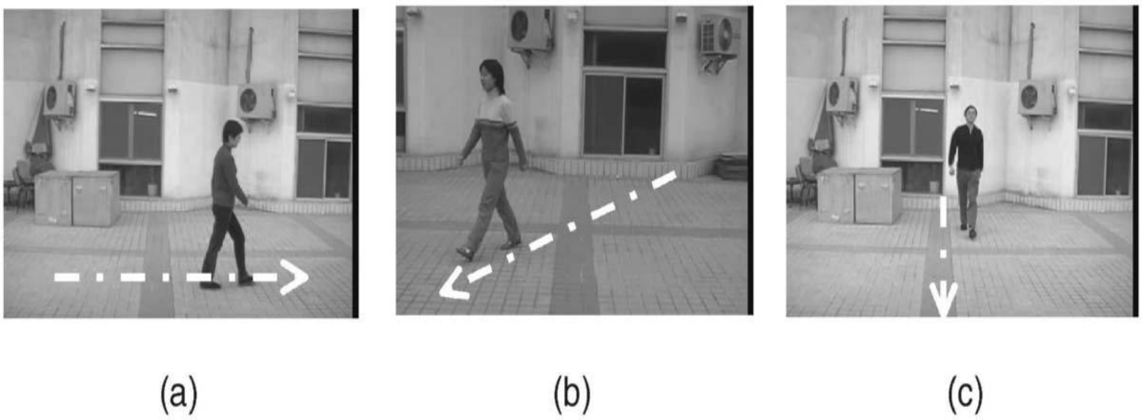

Fig. 2. Some Sample Images in the NLPR Gait Database: (a) Lateral View, (b) Oblique View, and (c) Frontal View

VII. DISCUSSION AND FUTURE WORK

To provide a general approach to automatic person identification in unconstrained environments, much remains to be done. We cannot conclude much about gaits. Further evaluation on a much larger and most-varied database is still needed. We are planning to set up such a database with more subjects, more sequences, and more variations in conditions. The across-day condition represents the hardest test of performance evaluation of a gait recognition method. This is due to same-subject differences caused by changing clothing (bulky versus thin), especially in different seasons. Our method is based on silhouette analysis; In fact, most past work is subject to the effect of shape Information due to the direct use of motion segmentation results. Creating more reference sequences with different shape may be of use to solve this problem. is The lack of generality of viewing angles is a limitation to most gait recognition algorithms. Our present method is view dependent like most previous work, so a useful experiment would be to determine the sensitivity of the features to different views, whose results would enable a multicamera tracking system to select an optimal view for recognition [5]. Another obvious way to generalize the algorithm itself is to store training sequences taken from multiple viewpoints and to classify both the subject and the viewpoint [22].

Also, seeking better similarity measures, designing more sophisticated classifiers, gait segmentation, and the evaluation of different scenarios deserve more attention in future work.

VIII. CONCLUSION

With the increasing demands of visual surveillance systems, human identification at a distance has recently gained more interest. Gait is a potential behavioral feature and many allied studies have demonstrated that it has a rich potential as a biometric for recognition. The development of computer vision techniques has also assured that vision based automatic gait analysis can be gradually achieved. This paper has described Different from gait classification which classifies human motion into categories, such as walking, running, and jumping, gait recognition, also called gait-based human identification, is a relatively new research direction in biometrics. It aims to discriminate individuals by the way they walk. In comparison with other first-generation biometric features such as fingerprint and iris, gait has the advantage of being unobtrusive, i.e., it requires no subject. Human identification at a distance has recently gained growing interest from computer vision researchers. Gait recognition aims essentially to address this problem by identifying people based on the way they walk. In this paper, a simple but efficient gait recognition algorithm using High Order Shape Configuration Gait has been known as an effective biometric feature to identify a person at a distance. However, variation of walking speeds may lead to significant changes to human walking patterns. It causes many difficulties for gait recognition. A comprehensive analysis has been carried out in this paper to identify such effects. Based on the analysis, Procrustes shape analysis is adopted for gait signature description and relevant similarity measurement. Although accomplished under some simplified assumptions like previous work, this work has been proven to be an encouraging progress to gait-based human identification.

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