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Human Gait Recognition: A Silhouette Based Approach

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***Abstract*—Human gait has become an important biometric in recent years. A silhouette based method is suggested in this paper, to recognize human in video by their gait. We used averaged silhouette to represent the gait cycle. Principal Component Analysis has been used to reduce the dimensionality of the features. We applied Euclidean distance to measure the similarity of the averaged silhouettes. We implemented the algorithm on the TUM-IITKGP Gait Database which has been introduced recently. Although this method is sensitive to the appearance of the subject, it has low computational cost and it is simple. We implemented two experiments on the achieved averaged silhouettes. Our results illustrated that feature extracted from the averaged silhouettes which in them, the lower part of the body is eliminated are more suitable rather than those extracted from the complete averaged silhouettes.**

***Index Terms*—gait recognition, averaged silhouette, principal component analysis, euclidean distance**

I. Introduction

The study of approaches to identify a human being based on physical or behavioral traits such as face, fingerprint, ear, voice, gait, iris, signature, and hand geometry is called biometrics. Each biometric has its relative benefits in various operational situations. Therefore, it is obvious that no single biometrics is expected to effectively fulfill all our concerns (e.g., accuracy, practicality, cost). Several human recognition approaches, such as fingerprints, face or iris biometrics, generally require a cooperative subject, or physical contact. These approaches can't be applied for non-cooperative subjects or in surveillance scenarios that identifying in distance is required. Gait recognition that is based on the way human walks is a biometric that is without the above-mentioned disadvantages [1].

Biomechanics [2] and psychophysical [3] studies illustrated that it is possible to achieve an almost unique signature from each individual's gait. First attempt of gait recognition in computer science was done by Niyogi and Adelson in 1994, their methodology was extracting spatiotemporal features from the subject's gait for recognition [4]. Afterwards, several studies implemented different gait recognition algorithms [5]-[7].

Gait recognition methods are generally divided into two different categories: model-based and appearance based. Model free gait recognition methods or appearance based methods work directly on the gait sequences. They don't consider a model for the human body to rebuild human walking steps. They have the advantage of low computational cost in compare with model-based approaches and they also have the disadvantage of sensitivity to cloth and appearance changing. There are several appearance based attempts in order to solve gait recognition problem [8]-[10].

Model-based approaches are those approaches which build a human body model and the extracted features of gait sequences will be fitted to that model. Model based approaches almost are not sensitive to the individual's appearance and clothing. On the other hand, model based approaches have high computational cost. Niyogi and Adelson [4] suggested the first model-based gait recognition approach by modeling human body into 5 sticks (2 sticks per legs, 1 stick for the body). Afterwards, several model-based approaches have been suggested by researchers [11]-[13].

II. Proposed Methodology

Human recognition based on gait is generally done by extracting the silhouette of the walking subject and analyzing it during walking. This paper proposes an appearance based recognition method applying the averaged silhouette of a subject during a gait cycle. Our proposed gait recognition approach consists of three basic stages: Human detection and Tracking, Feature Extraction and Training and Recognition. Fig. 1 illustrates an overview of the implemented method and each stage is described in details by the following sections.

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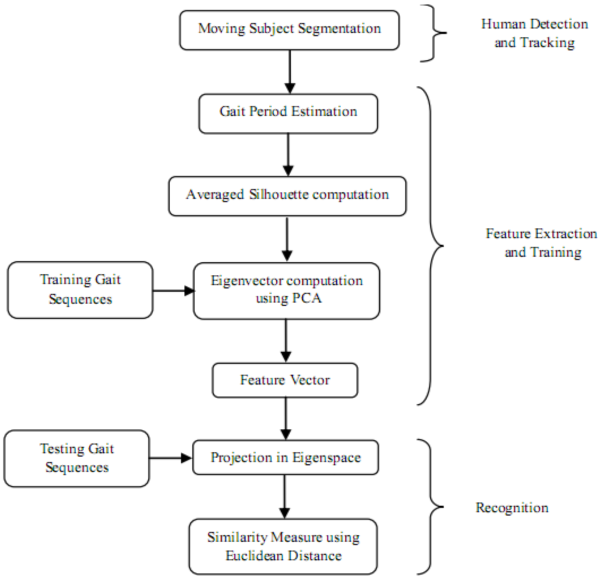

Figure 1. An overview of the implemented method.

A. Human Detection and Tracking

Generally, the first step in a gait recognition system is dividing video frames into background and foreground. This step's goal is achieving the binary silhouette of the walking subject. Since, we applied black and white gait sequences from TUM-IITKGP gait database in this study [14] which background was omitted in all gait sequences, we escaped this stage. We tracked the walking subject by, detecting the blob moving in each frame of the gait sequence. Then binary silhouettes of each frame were extracted and centralized. We also applied morphological operators to reduce the noises.

B. Gait period Extraction

A complete gait cycle is assumed as the time between three following initial swings. Initial swing is the phase that subject move the foot off the floor in order to take a stride. Simply talking, two following strides make a complete gait cycle. In this study, the gait cycle estimation has done by counting white pixels of the frames in a subject's gait sequence (see Fig. 2). Since, in initial swing phase, legs are becoming closer than the other phases, thus number of white pixels in a binary silhouette are approximately minimized. Therefore, we counted white pixel in each frame and we selected all frames which are located in between three minimum white pixel frames for a complete gait cycle.

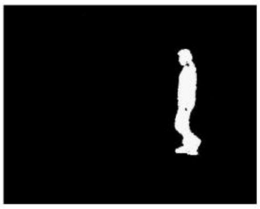

Figure 2. A frame sample, with an initial swing occurrence.

C. Averaged Silhouettes Computation

The gait representation method that applied in this paper is Averaged silhouettes [15]. Given all silhouettes in a complete gait cycle $Gc = \{Gc(1), Gc(2), \ldots, Gc(N)\}$, which N is the number of binary silhouettes in a gait cycle. In order to achieve a set of averaged silhouettes, $Avs = \{Avs(1), Avs(2)\ldots, Avs(i)\}$, we need to compute average of silhouettes in a gait cycle. For each subject, the averaged silhouette $(Avs(i))$ is achieved by

$$Avs(i) = \frac{1}{N}\sum_{l=1}^{N} Gc(l) \tag{1}$$

An example of the averaged silhouettes achieved in this study, is illustrated in Fig. 3.

D. Feature Extraction

Eigenspace transformation which is based on Principal Component Analysis (PCA) [16] is applied to the averaged silhouettes extracted from previous step. This step is implemented to reduce the dimensionality of the feature space. Let $Avs_1, Avs_2, \ldots, Avs_m$ be a set of m averaged silhouettes. The largest eigenvectors of the matrix

$$C = \sum_{i=1}^{m} Avs_i Avs_i^T \tag{2}$$

make a subspace that can rebuild the averaged silhouette with less dimensions. We applied a threshold to ignore small eigenvalues and their eigenvectors.

Figure 3. Averaged silhouette samples.

E. Recognition

The Euclidian distance is selected for the classification stage in this study. We need to compute the Euclidean distance of our input image with our training set. The Euclidean distance $d_E(A,B)$ between two vectorized averaged silhouette images Avs_A and Avs_B as size of $p \times r$, is obtained by

$$d_E(Avs_A, Avs_B) = \sqrt{\sum_{k=1}^{pr} (Avs_A^k - Avs_B^k)^2} \tag{3}$$

After Euclidean distance computation, the minimum Euclidean distance is selected as the result of recognition step.

III. Experiment

The TUM-IITKGP Gait Database [14] is used for this experiment. It contains 840 gait sequences from 35 different individuals. Each subject's sequences are recorded in 6 different conditions. However, all configurations are repeated two times from left to right and two times from right to left. Different recording conditions are considered, for each subject as regular walking, walking with hands in pockets, carrying a backpack, static occlusion and dynamic occlusion. All recording positions in the TUM-IITKGP Gait Database are side view. In this work, we applied normal walking from right to left gait sequences in the training and second recorded sequences of normal walking from right to left are applied as testing set. We implemented two experiments with the achieved averaged silhouettes. Baseline1 is our experience with the complete averaged silhouettes. Baseline2 is implemented by the averaged silhouettes which in them, the part that illustrates the legs are omitted and the recognition is done by the upper part of the body. Our recognition results show an improvement in the recognition rate in the Baseline2. Table I. illustrates the recognition rates of the suggested model.

IV. Conclusions

In this paper we applied an appearance-based gait recognition method that emphasizes on the silhouettes of the subject. Averaged silhouette which is a simple gait representation technique is applied as the gait representation technique. We computed the eigenvectors of the averaged silhouettes and projected them into feature space. Euclidean distance is used to compute the distance between the projected testing sample and the training samples as the recognition stage. This method is implemented on normal walking subjects of the TUM-IITKGP Gait Database.

TABLE I. Recognition Rates (%) of the Implemented Algorithm

	Correct Id Recognition	Wrong Id Recognition	False Rejection
Baseline 1	46	20	34
Baseline 2	60	37	3

We implemented two experiments with the averaged silhouettes and our results show that averaged silhouettes of the upper part of the body have gotten better recognition results in compare with complete averaged silhouettes.

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