International Journal of Future Generation Communication and Networking
Vol. 13, No. 3, (2020), pp. 659 - 665

Interval Based Speed Invariant Gait Recognition

Manjunatha Guru V G[1], Kamalesh V N[2]

[1]VTU RRC, Visvesvaraya Technological University, Belagavi, Karnataka, India & GFGC, Honnali, Karnataka, India.
[2]Professor and Dean, T-John Institute of Technology, Bangalore, Karnataka, India.
[1]Email: vgmanjunathji@gmail.com
[2]Email: kamalesh.v.n@gmail.com

Abstract

This paper has revealed the benefits of multi interval features in the field of gait recognition. For each normalized silhouette, the outer contour is constructed by considering only the leftmost and rightmost pixels. Then, distance vector is generated by computing distances between the leftmost and rightmost pixels. The same technique is applied to all silhouettes of an individual. At the end, feature matrix is obtained by concatenating the distance vectors in row wise. Further, multi interval features are generated by considering the each column of feature matrix. In this work, a new similarity matching technique between the gallery and probe interval is proposed. Finally, nearest neighbor classifier is used for the classification procedure.

Keywords: *Distance vector; Human gait; Intervals; Outermost contour; Similarity*

1. Introduction

Human gait recognition newly increased a wider attention from computer vision research community because of its rich volume of merits. A gait biometric source has voluminous benefits compared to conventional biometric sources such as iris, face, finger print, signature, speech and hand geometry, etc. Gait recognition is the methodical study of human bipedal motion, more specifically the study of human walking. Gait has been established as behavioral biometric source to recognize people by the way they walk. Human gait usually comprise of both physiological and psychological state of humans. Hence, it is also referred as a behavioral biometric source. Gait does not need physical cooperation and even attentiveness of the individual under observation. Also, it can be acknowledged from at a greater distance. However, gait is becoming standard biometric source in security sensitive locations, i.e. government secretariats, airports, banks, and public transport stations etc. Furthermore, the latest advances in gait recognition have led to the development of techniques for forensics, initial finding of Parkinson disease and effective sports training device etc. [18][20][21][22][24][25][26]

1.1. Single Valued Features

Wang et al [1] have explored procrustes shape analysis method to obtain mean shape as gait signature. Dacheng et al [4] have discovered the three different Gabor function based image representations which were created from the averaged gait images. Further, general tensor discriminant analysis (GTDA) was used as an initial step for LDA. Heesung et al [5] have incorporated recursive PCA reconstructions to reduce the effects of backpack from the gait energy image. Puspha et al [6] have incorporated morphological skeleton operator to represent the gait information of an individual.

Gil et al [17] has explored a MIP (Motion Interchange pattern) framework which encodes dynamicity by extracting local variations in motion directions. Erhu et al [8] have explored active regions based gait representation method (i.e. Active Energy Image). Further, 2DLPP (Two Dimensional Locality Preserving Projections) method was incorporated to improve the features. Yu et al [10] explored a classifier ensemble framework by incorporating RSM (Random Subspace Method) in order to accomplish the speed invariant gait recognition system. Yumi et al [11] have partitioned the human body into multiple blocks. In their work, each block contributes to the final feature vector. Parul et al [19] have explored a GHGI (Gradient Histogram Gaussian Image) based gait representation method. In their, they have applied HOG (Histogram of Oriented Gradients) to extract the features from the GGI (Gait Gaussian Image).

1.2. Interval Features

Mohan Kumar et al [9] [12-15] have only examined the evidences of interval features for the first time in the field of gait recognition. They have investigated many significant interval features based approaches to effectively solve the gait identification problem under commonly occurred practical conditions [9] [12-15]. In work [9], interval feature vector was generated by extracting the simple properties like width, height, distance between two feet and ratio of height to width. In [12], authors have explored a fusion based technique by extracting the simple properties like width, height, step length and axis of least inertia from the each silhouette. In work [13], authors have explored block based technique by dividing the GEI into 4 equal areas. Further, LBP (i.e. Local Binary Pattern) procedure was applied on each area. In work [14], authors have examined the competence of interval features by applying Radon transformation on the CEI images (i.e. change energy images). In work [15], authors have used the LBP method to GEI and to the RBL (region bounded by legs) of GEI. Manjunatha Guru et al [23] have also examined the ability of interval features for the effective gait identification process even in the presence of gait covariate factors.

2. Proposed Method

2.1. Pre-processing

In this paper, we have used one of the major speed invariant dataset i.e. CASIA(C). It is freely available and significantly largest dataset. This dataset directly provide the raw silhouettes to the gait research community. In this dataset, each person's gait information is represented as the sequence of silhouettes.

Morphological operators are more important in order to improve the quality of silhouettes. For each silhouette, these operators are used to reduce the noise and holes in the silhouette. Also, it is used to bridge the gaps in contour of the silhouette. Further, bounding rectangle was used to crop the human body. Then, it was resized to fixed dimension (i.e. 128 X 88) and also aligned horizontally. The same procedure was applied to all silhouettes of an individual.

2.2. Interval Features

The walking speed of the same subject changes over time due to physical and psychological factors. Hence, single valued features are not effective to handle different walking speed conditions. However, interval features are more significant to achieve the speed invariant gait recognition system. Since, intervals symbolize the gait information in the form of range (i.e. minimum to maximum).

For each normalized silhouette (i.e. 128 X 88) of an individual, distance vector is obtained by considering only the left most and right most pixels. The pixels between legs are not included to this distance vector. The below Figure 1 depict our proposed schematic of distance vector. For each row, distance (i.e. D) is calculated between the left most and right most pixels. However, the length of the distance vector is 'H' (i.e. height of the normalized silhouette). The same has applied to all normalized silhouettes of an individual. Finally, feature matrix (f_m) is generated where columns represent the number of features (i.e. H) and rows represents the number of silhouettes of an individual (i.e. N). Therefore, the size of the feature matrix 'f_m' is NXH. The below equation (1) depicts the sample structure of feature matrix.

Figure 1. Schematic of proposed representation

$$f_m = \begin{pmatrix} D_{11} & \cdots & D_{1H} \\ \vdots & \ddots & \vdots \\ D_{N1} & \cdots & D_{NH} \end{pmatrix} \tag{1}$$

For each column of 'f_m', mean and maximum operations are used to construct the interval feature. The mean value indicates the lower bound of an interval. Likewise, maximum value indicates the upper bound of an interval. The below equations (2), (3) and (4) shows the calculation of interval feature for the first column. Further, the same procedure has applied for the remaining columns. At the end, the final feature vector (i.e. F) is generated with consisting of 'H' interval features as indicated in the equation (4).

$$\mu_1 = mean(D_{11}, D_{21}, ..., D_{N1}) \tag{2}$$

$$M_1 = \max(D_{11}, D_{21}, ..., D_{N1}) \tag{3}$$

$$F = (I_1 = [\mu_1 - M_1], I_2 = [\mu_2 - M_2], ..., I_H = [\mu_H - M_H]) \tag{4}$$

2.3 Similarity Measure & Classification

As indicated in equation (5), the probe sample 'P' = {P_1, P_2,…,P_H} is feature vector which consist of 'H' intervals. Likewise, the gallery G_j = {g_{j1},g_{j2},…,g_{jH}} ∀ j=1…M is a set of 'M' number of samples. In that, each gallery sample is represented as the interval based feature vector. In the below representations of 'P' and 'G', the symbol '-' refers to lower bounds and '+' refers to upper bounds of an intervals.

$$P = \left\{ P_1 = \left[p_1^-, p_1^+ \right],\ P_2 = \left[p_2^-, p_2^+ \right], \ldots,\ P_H = \left[p_H^-, p_H^+ \right] \right\} \tag{5}$$

$$G_j = \left\{ g_{j1} = \left[g_1^-, g_1^+ \right],\ g_{j2} = \left[g_2^-, g_2^+ \right], \ldots,\ g_{jH} = \left[g_H^-, g_H^+ \right] \right\} \tag{6}$$

Let 'S_j' be the matrix which is constructed by computing the two different similarities between the probe sample and the samples which are in the gallery. Therefore, the size of matrix is M X 2 (Where 'M' is the number of gallery samples). The equation (7) represents the schematic structure of similarity matrix (S_j). At the end, the final similarity matrix of size M X 1 is obtained by calculating the mean value in each row of 'S'. The maximum value in the matrix represents the high similarity. Likewise, minimum value represents the low similarity. Finally, the probe sample belongs to the class label which possesses the maximum similarity value.

$$S_j = \left\{ s_{j1}, s_{j2} \right\} \forall\ j = 1 \ldots M \tag{7}$$

Where

$$s_{j1} = \sqrt{\sum_{i=1}^{H} Sim_1 \left(p_i, g_{ji} \right)^2}$$

$$s_{j2} = \sqrt{\sum_{i=1}^{H} Sim_2 \left(p_i, g_{ji} \right)^2}$$

Where

$$Sim_1 = \left\{ \begin{array}{ll} 0 & no\,overlap\,between\ \ p_i\ and\ g_{ji} \\ \hline \dfrac{\left| p_i \cap g_{ji} \right|}{\left| p_i \right|} & Overlap\,exist \end{array} \right\}$$

$$Sim_2 = \left\{ \begin{array}{ll} 0 & no\,overlap\,between\ \ p_i\ and\ g_{ji} \\ \hline \dfrac{\left| p_i \cap g_{ji} \right|}{\left| g_{ji} \right|} & Overlap\,exist \end{array} \right\}$$

3. Experimental Results on CASIA (C) Dataset

CASIA C Dataset is one of the largest speed invariant dataset which consist of 153 subjects. This dataset consists of two significant gait practical conditions such as backpack and different walking conditions. Each subject consists of 10 sequences (i.e. 2 backpack, 4 normal walk, 2 fast walk and 2 slow walk sequences). However, it consists of totally 1,530 sequences (i.e. 153 subjects X 10 sequences per subject). We conducted two different experiments to investigate the efficiency of interval features under backpack and speed conditions.

3.1. Experiment – 1

In this experiment, normal walking sequences are considered as the gallery set and the backpack sequences are considered as the probe set. For each subject, 4 normal walking sequences are used as a gallery set and 2 backpack sequences are used as a probe set. However, total 612 sequences are considered as a gallery set and 306 sequences are considered as a probe set. For this experimental plan, our proposed approach has achieved 98.03% of CCR (correct classification rate).

3.2. Experiment – 2

The entire dataset is partitioned into three sets namely normal walk, slow walk and fast walk. In each test, one set is used as a gallery set and the remaining two are used as a probe set. The same kind of setting has repeated for the three times. For this experiment plan, our proposed approach has achieved 96.40% of average CCR by considering the 3 different walking speed conditions.

4. Comparative Analysis on CASIA (C) Dataset

In this work, we investigated the effectiveness of our proposed approach by incorporating the same experimental plan and settings which are presented in most of the current literatures. Table 1 show our proposed result for the below mentioned experimental settings and also, the comprehensive comparison results on recent existing gait literatures.

Table 1. Comparative Results

Methods	Gallery	Probe	Result
Erhu et al [7]	Normal walking sequences	Slow walk, Fast walk and Backpack	88.9%
Proposed Approach			99.01%
Yu et al [10]	Three normal walking sequences	2 fast walk + 2 slow walk + 1 normal walk + 2 back packs	98.87%
Proposed Approach			98.97%

5. Conclusion

This paper has examined the qualities of interval features in the gait identification system even in the existence of gait covariate conditions. In a practical scenario, different walking speed conditions are more noticeable in the gait recognition system compared to other gait covariates. Since, an individual can walk at any speed depending on the psychological factors such as relax, stress, and hurry etc. Therefore, single valued type features are not appropriate for the effective gait recognition. Also, it cannot properly describe the gait information under different walking speed conditions. However, interval valued type features are effectively examined in this work. The experimental outcomes are matched with the contemporary approaches in the gait literature. The comparative analysis has clearly revealed that our proposed approach is superior to other existed works in the current gait literature.

Acknowledgements

The authors would like to thank the creators of CASIA C dataset for providing the publicly available gait dataset.

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Authors

Manjunatha Guru V G, received his MCA degree from Visvesvaraya Technological University in 2011. He is pursuing Ph.d (Part Time) in Computer Science and Engineering from Visvesvaraya Technological University, Belagavi, Karnataka, India. Also, he is presently working as Assistant Professor & Head, Department of Computer Science, Government First Grade College, Honnali – 577217, Davanagere District, Karnataka, India. He is having 7 years of experience in teaching and research. He has published research papers in the international journals and in the conference proceedings. His research interests include computer vision, digital image processing, video processing, pattern recognition, algorithms and biometrics. Email: vgmanjunathji@gmail.com

Kamalesh V N, Professor and Dean in the Department of Computer Science and Engineering, T John Institute of Technology, Bangalore, Karnataka, India. Previously, he worked as Special Officer for e-Learning Department, Visvesvaraya Technological University, Mysore Region. He obtained Ph.d in Computer Science and Engineering from Satyabhama University. He is having 25 years of experience in academics, research and administration. He has published several papers in the international and national journals and in the conference proceedings. He received national and international awards for academics and research. His area of research is algorithms, biometrics, graph algorithms, image Processing, pattern recognition and technology for education. Email: kamalesh.v.n@gmail.com