Research on the Application of Curve Fitting in Gait Recognition

[1]Wen Che, [1]Li Hua and [2,*]Zhou Chunlai

Abstract

Gait recognition technology has become a new research hotspot in the field of biometric recognition in recent years. Compared with other biometric features, the human gait is the most potential for the identification of biological characteristics, which has aroused the interest of the majority of researchers. A method for the application of curve fitting to the gait recognition is presented in this paper. In this paper, the process of extraction, credibility and original data preprocessing is firstly introduced, and then the method of smoothing spline curve fitting is shortly analyzed. Next, the coordinate data of the ankle and the knee in the process of human walking are extracted, and the method of calculating their similarity is proposed. Finally, the effectiveness of the proposed method is verified by the actual test.

Keywords: gait recognition, curve fitting, reliability degree, similarity degree

1. Introduction

Gait refers to the characteristics of the human body during walking [1]. Gait can be used as an effective biological identification method to identify the human's identity as the result of each person's posture in different ways [2]. The gait recognition technology is used in the field of biological identification in 1994, proposed by Niyogi and Adelson [3-5]. Since then, gait recognition technology has attracted more and more people's attention. They began to get a wide range of research.

As an important branch of pattern recognition, gait recognition technology includes three processes: gait detection, feature extraction and gait recognition [6-8]. Many literatures have made a deep research on these three processes. In gait detection methods, there are active contour model method [9], Hausdorff method [10], inter frame difference method [11-12] and background subtraction method [13], optical flow method [14], etc. In the aspect of feature extraction, the methods are mainly divided into two kinds, the structural characterization methods and the non structural characterization methods. In the methods of structural representation, there are the pendulum model proposed by literature [15], the five link biped model proposed by literature [16]; and the literature [17] proposed a model of the whole body stratification.

In non structural characterization methods, some of the literature presents a contour of the unwrapping gait recognition method [18]; some of the literature presents in the 1D gait signal based on wavelet packet transform method of gait feature [19]; and some of literature combined the outline width and the profile as gait feature extraction [20]. From the above introduction, a conclusion can be drawn that in the field of gait recognition, the methods are varied. Each has its own distinctive characteristics. However, from the practical application of these methods in gait recognition, they are easy to be affected by environmental factors, the detection is not accurate, and the recognition accuracy is not high [21-23]. In the actual gait recognition process, the effect of the application is not obvious, which can not meet the practical requirements. It is aimed to solve this problem in this paper.

2. Gait Feature Detection

2.1 The Detection of Gait Feature

Due to the popularity of the camera and video recording equipments, the camera or video recorder has become the most convenient and economical way to detect the feature of gait recognition. Because of this, the method of setting the camera on the ground to get the characteristic data of the gait recognition is chosen in this paper. Taking that the distance of the object in the practical application is too close to the camera equipment, and there are the environmental interference and other factors into account, the following settings are set up in the experimental environment in this paper. The common digital cameras are located about 30cm from the ground, the coverage range of camera is 1-2m, and the distance between the camera and the person who is walking is 0.5m. When the image is being collected, the digital camera is always fixed on the ground. The time interval of each frame is 0.05s. After the experiment, the photos obtained are shown in Figure 1.

*Corresponding Author: Zhou Chunlai
(E-mail: clzhou@cuc.edu.cn)
[1]School of Electrical Engineering, Hebei University of Technology, Tianjin, China,300130
[2]The School Of Information Engineering, The Communication University of China, Beijing, China, 100024

Figure 1: Original photo obtained by experiment

In the selection of the object, the detection speed and accuracy of the model have been taken into account in this paper. Therefore, the ankle and knee have been chosen as the target to be detected. The specific method of obtaining the characteristic is to set the point of the upper left corner of the original photograph as the origin of the coordinate system to establish the X-Y coordinate system. And then get the ankle coordinate [x1, y1] and knee coordinate [x2, y2] of the walking person. In this case, the distance between the knee point and ankle point of the same person should not changed in the experiment. Therefore, the distance $S=\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$ between the knee point and ankle point is an important parameter to judge the validity of the data collected. In a certain experiment, the test data is shown in Table 1.

Table 1: The coordinates of the ankles and knees of the subjects

Ankle coordinates (CM)	Knee coordinate (CM)	Distance (CM)
[13.55,84.67]	[24.34,27.71]	57.97
[14.18,84.24]	[29.21,29.85]	56.43
[14.61,84.03]	[33.66,30.90]	56.44
[14.82,83.40]	[36.41,30.48]	57.15
[14.82,82.76]	[37.68,34.08]	53.78
[16.72,79.59]	[46.36,34.93]	53.60
[21.38,75.14]	[55.03,33.66]	53.41
[27.73.70.27]	[67.52,31.75]	55.38
[47.84,67.73]	[90.59,34.08]	54.40
none	[114.94,28.79]	none

As it can be seen from Table 1, the ankle data of the detected person in the experimental environment is blocked by other objects, or some of the original photos are blurred because of the camera's own problem. Therefore, the data cannot be located., and it is necessary to take the data of the original photograph into pre-treatment.

2.2 The Credibility and Pre-treatment of Original Data

In the actual gait recognition process, it is not possible to obtain only one set of data for the same time. It must obtain a lot of sets of data in different times. In order to obtain more accurate recognition results in the process of gait recognition, the initial data from several groups in the experiment must be selected. The concept of data credibility is introduced here, and the credibility degree of the data is expressed as:

$$c=\frac{1}{d} \tag{1}$$

In the formula, d is the sample variance of the distance S between the knee and ankle in the data group. For example, the sample variance of the knee and ankle distance of the participants in this set of data as shown in Table 1 is 2.51, so the credibility of this group of data is 0.40.

Assume that the reliability degrees of the two sets of data obtained in the experiment are respectively c_1 and c_2. And the relationship between c_1 and c_2 is as follows: $c_1 > c_2$. Therefore, in the process of gait recognition, the data whose credibility degree is c_1 is chosen to improve the accuracy of gait recognition.

Obviously, due to the placement of the digital camera in the experiment, the shooting angle, as well as the environment in the experiment, the disturbance of stroke and foreign body occlusion and other issues, there must be noise interference in the selected group of original data after compared by the size of the credibility. For example, in the 10th frame in the Table 1, due to the impact of various factors, the ankle coordinates of the side legs of the camera equipment is not obtained in this experiment, so this phenomenon is called the lack of original data. Assume that the data is $[x_1,y_1],[x_2,y_2],\ldots,[x_n,y_n]$. When the phenomenon of data loss occurs, the following treatment should be taken:

(1) When the missing data is $[x_1,y_1]$ or $[x_n,y_n]$: The missing data is not processed. Use the rest data to carry out the operation of the gait recognition.

(2) When the missing data is $[x_k,y_k],\ k\neq 1, k\neq n$, calculate the average value of two data on both sides of missing data to fill the missing data.

$$\begin{cases} x_k = \dfrac{x_{k-1}+x_{k+1}}{2} \\ y_k = \dfrac{y_{k-1}+y_k}{2} \end{cases} \quad (2)$$

(3) If the data on both sides of the missing data are still not normal data, select the data on both sides before and after the two noise data, Calculate the substitution value of two noise data in accordance with the arithmetic way. Assume that the missing data are x_k and x_{k+1}, the normal data are x_{k-1} and x_{k+2} ,there are:

$$\begin{cases} x_k = \dfrac{2x_{k-1}+x_{k+2}}{3} \\ x_{k+1} = \dfrac{x_{k-1}+2x_{k+2}}{3} \end{cases} \quad (3)$$

2.3 Curve Fitting of Gait Characteristic Data

In gait recognition, a linear function relationship does not exist in different variables for human of walking postures. Therefore, in order to reveal the relationship between variables, the appropriate type of curve to fit the data obtained in the experiment need be selected. In addition, in this paper, the human body model is simplified to a two-point model of the ankle and knee. Compared to other gait recognition methods (such as the use of various kinds of artificial intelligence algorithm of gait recognition method), the curve fitting method not only remains at a high level in recognition accuracy, but also it has the advantages of simple procedure, fast operation speed, less hardware support and so on[24-26]. Therefore, in this paper, a deep research will be taken on the application of curve fitting in gait recognition.

There are many kinds of curve fitting, such as Fourier function fitting, exponential function fitting, logarithm function fitting, interpolation function fitting, Bessel curve fitting and so on. The Fourier function fitting has some stringent requirements for the number of parameters. In addition to the input data, the Bessel curve fitting requires additional control points, and the control points have great influence on the fitting results. After the analysis, comparison and experiment, the calculation method of interpolation function fitting method which has the wide range of application is used to fit the experimental data in this paper.

According to the data as shown in Table 1, cubic spline curve fitting and smoothing spline curve fitting operation have been carried out. The fitting results are shown in Figures 2 and 3.

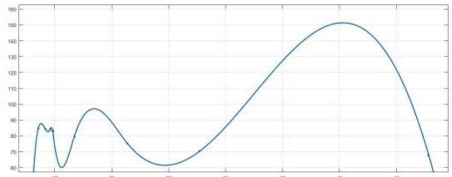


Figure 2: Cubic spline curve fitting

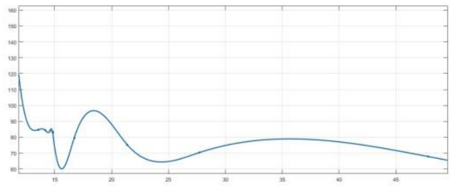


Figure 3: Smooth spline curve fitting

From Figures 2 and 3, the conclusion can be drawn that in the fitting process of the relevant data in Table 1, the fluctuation of cubic spline curve is much greater than smoothing spline curve. In order to have the stability and avoid the fitting error, the smoothing spline curve is used to fit the data obtained in the experiment in this paper.

Smoothing spline is a common method of spline interpolation and curve. Compared with other interpolation methods, the advantage of the smoothing curve interpolation method is that the smoothness of the piecewise linear interpolation function is improved.

For the given $n+1$ different nodes $x_i(i=0,1,L,n)$, and their function values are $y_i(i=0,1,l,n)$ .The mathematical functions are constructed to satisfy that:

(1) $f(x)$ has two order continuous derivative on $[a,b]$.

(2) $f(x_k)=y_k(k=0,1,2,L,n)$.

(3) $f(x)$ is the three degree polynomial in each sub region $x_{k+1}(k=0,1,2,L,n)$.

This is the mathematical principle of smoothing spline curve.

3. Design of Gait Recognition System

3.1 Process Design of Gait Recognition System

In this paper, in the process of gait recognition researching, the human body model in walking is simplified to the two points of the ankle and the knee. The gait recognition system designed in this paper is mainly used in the occasion that the flow of people is high, such as subway station, railway station and airport. It has advantages that the detection speed is high, and the demand for the photographic equipment is low. In this paper, the main design idea of the gait recognition system is to use the camera equipment to continuously shoot the walking people at the same time interval. Then set the upper left corner of the photo as the origin to establish the coordinate system, Record the coordinates of the data, with each 10 data for a set of records to the database. Put the set of data which has the largest reliability degree after calculating into the process of gait recognition. The specific workflow of the gait recognition system is shown in Figure 4.

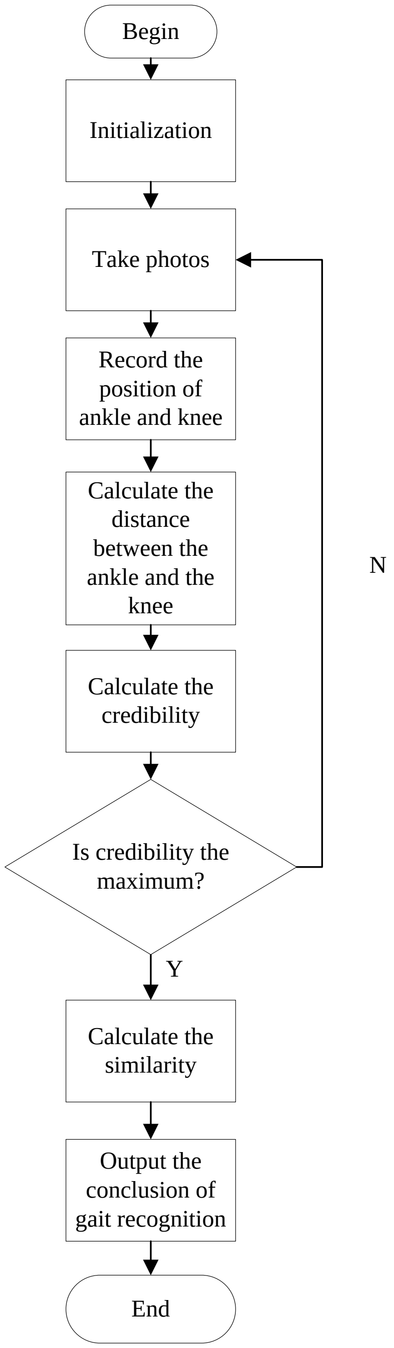


Figure 4: The flow chat of gait recognition system

3.2 Design of Feature Acquisition Process

Acquisition of gait features is an important step in the process of gait recognition. The so-called gait characteristics refers to the information collected in the true response to each person's unique walking posture with part of the characteristic. In other literature, some selected the foot step as gait feature, and others selected the pace as the gait feature. In fact, these methods want to increase the accuracy of gait recognition by focusing on the speed and acceleration information of walking gait.

However, under normal circumstances, the equipment of gait recognition is the ordinary digital camera, not equipped with devices that can directly detect the foot step and pace of walking persons. The idea to obtain step or pace feature through the analysis of the camera shooting pictures is not very realistic and accurate. Therefore, in this paper, the coordinates of the ankle and the knee obtained from the pictures are taken as the gait feature. And based on this feature, the degree of similarity can be calculated between the two times of walking.

Gait recognition is actually a process of comparison and judgment. There are only two kinds of results after the gait recognition process:

1. The two walking patterns are not similar. They are not the same person.
2. The similarity degree of two walking patterns is high. It is the same person.

In this comparison and judgment process, the similarity between the curve fittings of two times walking judged by eyes is not enough. The quantitative analysis must be introduced. Therefore, the concept of similarity is introduced in this paper. The similarity between the two walking in the process of gait recognition is defined as the similarity degree, which is expressed as h. The similarity degree h represents the result of gait recognition. The greater the h, the higher the degree of similarity between the two walking. On the contrary, when the h is smaller, the possibility that different persons walk is higher. The calculation method of h is deduced in detail below.

Assume that the ankle coordinate data collected through the two walks are $\{(x_1,y_1),(x_2,y_2),...,(x_{10},y_{10})\}$ and $\{(a_1,b_1),(a_2,b_2),...,(a_{10},b_{10})\}$. For ankle coordinates, the similarity degree h_1 is:

$$h_1 = \frac{0.5}{1+w_1\sqrt{[(x_1-a_1)^2+...+(x_{10}-a_{10})^2]}} + \frac{0.5}{1+w_2\sqrt{[(y_1-b_1)^2+...+(y_{10}-b_{10})^2]}} \quad (5)$$

In the formula, w_1, w_2 are the weight coefficients. The role of weight coefficient is to adjust the amplitude of the similarity, so that when the data slightly changes, the change of the similarity degree is not too small. When the data changes dramatically, the change of the similarity degree is not too large.

From the Formula 5, a conclusion can be drawn that the maximum value of the similarity degree h_1 is 1. When the similarity degree h_1 is 1, it shows that the two walks are exactly the same. There is no difference between them.

Similarly, knee data collected in two times of walks can be used to calculate the coordinates for the coordinates of the knee similarity degree. The calculation methods of h_1 and h_2 are the same, so it is not reiterated here.

Therefore, the whole process of gait recognition similarity is h, its size is equal to the smaller one between h_1 and h_2, that is:

$$h = \min\{h_1, h_2\} \tag{6}$$

After reading literature and experimental verification, it can be drawn in generally, the similarity degree of the two walks with the same person is more than 0.95, but the similarity between two walks with the different persons is less than 0.75. It indicates that the effect of similarity on gait recognition is obvious.

4. Results and Analysis of Experiment

In this paper, it not only presented a gait recognition method based on curve fitting, but also designed relevant experiments to verify the correctness and effectiveness of the gait recognition method..

Taking into account that in the actual gait recognition process, the results is similar or not similar; the experiments are designed for these two cases:

(1) Two walks with the same person.

(2) Two walks with the different persons.

After several tests on these two cases, the following results are obtained.

In the experiment, the pictures taken by the camera are shown in Figure 5.

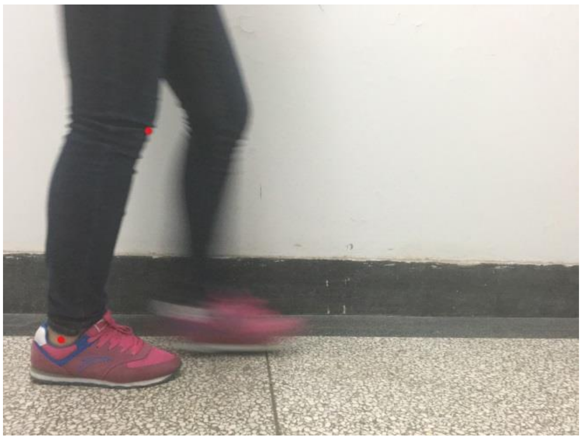


Figure 5: Walking photograph obtained in the experiment

The two red dots in the Figure 5 represent the marks of the ankle and the knee. Their coordinates are [14.82] and [83.40].

Table 2: The coordinates of the ankles and knees of two walks with the same person

Ankle coordinates (CM)	Knee coordinate (CM)
[13.55,84.67]	[24.34,27.71]
[14.18,84.24]	[29.21,29.85]
[14.61,84.03]	[33.66,30.90]
[14.82,83.40]	[36.41,30.48]
[14.82,82.76]	[37.68,34.08]
[16.72,79.59]	[46.36,34.93]
[21.38,75.14]	[55.03,33.66]
[27.73.70.27]	[67.52,31.75]
[47.84,67.73]	[90.59,34.08]
none	[114.94,28.79]
Ankle coordinates (CM)	Knee coordinate (CM)
[14.56,83.82]	[22.28,28.31]
[14.95,83.53]	[27.85,30.13]
[15.33,83.11]	[31.59,31.23]
[16.02,80.12]	[34.88,30.97]
[16.04,79.65]	[36.01,34.85]
[18.37,77.22]	[45.97,35.24]
[23.76,75.83]	[54.29,34.96]
[28.94,72.66]	[66.27,32.25]
[49.13,70.29]	[88.92,35.61]
[50.11,66.15]	[112.85,29.73]

Table 2 shows the coordinate data of the ankle and knee in the gait recognition system in the process of two walks with the same person. According to the data in the table, the fitting curve can be made as shown in Figures 6 and 7.

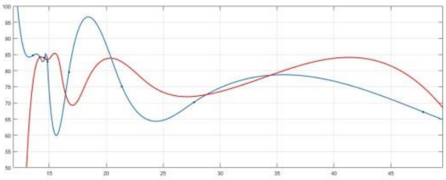


Figure 6: The curve fitting of coordinates of the ankles in two walks with the same person

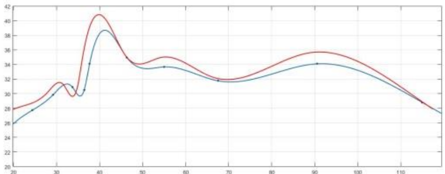


Figure 7: The curve fitting of coordinates of the knees in two walks with the same person

From Figures 6 and 7, it can be drawn that the gait recognition method based on curve fitting has a good ability to distinguish the two walks of the same person.

In Figures 6 and 7, the blue curve is the curve fitting of first walk. The red curve is the curve fitting of second walk. It can be clearly seen that the red curve and the blue curve of the degree of fit are very high. In particular, according to the curve of the knee data fitting, the two curves in some parts are of the near coincidence. This also illustrates the effectiveness of the gait recognition method based on the curve fitting proposed in this paper. Then calculate the similarity of the two walks with the same person.

According to the content introduced in Section 3.2, it can be calculated $h_1 = 0.975$, $h_2 = 0.984$, so from $h = \min\{h_1, h_2\}$ can know that $h = 0.975$, This result shows that the similarity of the two walking is very high, which proves the accuracy of the method for the same person walking process proposed in this paper.

According to the process of the two walking of different people, the experiment obtained the data as shown in Table 3.

Table 3: The coordinates of the ankles and knees of two walks with the different persons.

Ankle coordinates (CM)	Knee coordinate (CM)
[13.55,84.67]	[24.34,27.71]
[14.18,84.24]	[29.21,29.85]
[14.61,84.03]	[33.66,30.90]
[14.82,83.40]	[36.41,30.48]
[14.82,82.76]	[37.68,34.08]
[16.72,79.59]	[46.36,34.93]
[21.38,75.14]	[55.03,33.66]
[27.73.70.27]	[67.52,31.75]
[47.84,67.73]	[90.59,34.08]
none	[114.94,28.79]
Ankle coordinates (CM)	Knee coordinate (CM)
[20.65,73.89]	[40.89,50.12]
[31.54,65.98]	[43.27,51.22]
[38.83,77.28]	[45.88,54.92]
[49.29,80.91]	[50.49,58.10]
[50.83,90.20]	[52.84,60.81]
[56.48,78.26]	[53.31,50.91]
[60.41,85.24]	[54.29,48.33]
[68.04,96.81]	[66.27,52.69]
[69.19,85.27]	[88.92,59.12]
[75.34,80.75]	[90.24,60.26]

Table 3 shows the coordinate data of the ankle and knee in the gait recognition system in the process of walking with two different people. According to the data in the table the fitting curve can be made as shown in Figures 8 and 9.

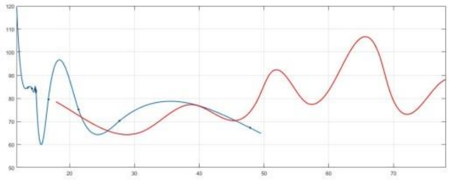


Figure 8: The curve fitting of coordinates of the ankles in two walks with the different persons

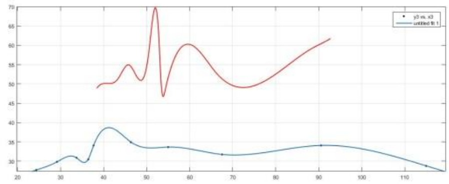


Figure 9: The curve fitting of coordinates of the knees in two walks with the different persons

From Figures 8 and 9, it can be drawn that the gait recognition method based on curve fitting has a good ability to distinguish the two walks of the different persons.

In Figures 8 and 9, the blue curve is the curve fitting of first walk. The red curve is the curve fitting of second walk. It can be clearly seen that the correlation between the red curve and the blue curve is very low. In particular, according to the knee data fitting curve, the two curves are completely not related. This also illustrates the effectiveness of the gait recognition method based on the curve fitting proposed in this paper. Then calculate the similarity of the two walks with the different persons.

According to the content introduced in Section 3.2, it can calculate $h_1 = 0.532$, $h_2 = 0.618$. So from $h = \min\{h_1, h_2\}$ can know that $h = 0.532$. This result shows that the similarity of the two walking is very low, which proves the accuracy of the method proposed in this paper.

5. Conclusions

Firstly the concept of gait recognition is introduced, and the three processes of gait recognition including gait detection, feature extraction and gait recognition are pointed out. In the process of gait detection, the method of obtaining the data from the photograph is introduced in this paper. And the concept of credibility and the method to process the data under the condition of data loss is put forward. In the process of feature extraction and gait recognition, the process of gait recognition system is designed, and the calculation method is proposed to calculate the similarity between two walks.

A gait recognition method based on smoothing spline curve fitting is proposed in this paper. Get the relevant data of person in walking. Then use smoothing spline curves to fit the data, and then extract the characteristic quantity. Finally, the whole curve fitting process is completed through the method of calculating the similarity. The actual test shows that the gait recognition method based on smoothing spline curve fitting can be effective for accurate gait recognition of the same person and different persons. It has great development research space and great practical value.

References

[1]. Cho C W, Chao W H, Lin S H, "A Vision-Based Analysis System for Gait Recognition in Patients with Parkinson's Disease" , Expert Syst With Appl,Vol.36, No.3, pp.7033-7039, 2009.

[2]. Little J, Boyd J, "Recognizingm people by their gait: the shape of motion" , Jouranl of Computer Vision Research, Vol.2, pp.2-32, 1998.

[3]. Niyogi S A, Adelson E H, "Analyzing gait with spatiotemporal surfaces", Proc.of IEEE Workshop on Non-grid Motion, pp. 24-29, 1994.

[4]. Murase H, Sakai R, "Moving object recognition in eigenspace representation gait analysis and lip reading", Pattern Recognition Letters, Vol.17, No.2, pp.155-162, 1996.

[5]. Han J, Bhanu B, "Performance prediction for individual recognition by gait", Pattern Recognition Letters, Vol.26, No.5, pp.615-624, 2005.

[6]. Wang L, Tan T, Ning H, et al, "Fusion of static and dynamic body biometrics for gait recognition" , IEEE Transactions on Circuits and Systems for Video, Vol.14, No.12, pp.149-158, 2004.

[7]. Trivino Q, Alvarez A, Bailador G, "Application of tiie computational tiieory of perceptions to human gait pattern recognition", Pattern Recognition, Vol.43, No.7, pp. 2572-2581, 2010.

[8]. Bashir K, Xiang T, Gong S G, "Gait recognition without subject cooperation", Pattern Recognition Letters, Vol.31, No.13, pp. 2052-2060, 2010.

[9]. Blake A, Isard M, Active Contours, Berlin:Springer, 1998.

[10]. Park S C, Lee S W, "Object Tracking with probabilistic hausdoff distance matching", Proceedings of International Conference on intelligent computing, Hefei, China, pp.233-242, 2005.

[11]. Saghafi B, Rajan D, "Human action recognition using Pose-based discriminant embedding", Signal Processing: Image Communication, Vol.27, No.1, pp.96-111, 2012.

[12]. Tafazzoli F, Safabakhsh R, "Model-based human gait recognition using leg andarm movements ", Engineering Applications of Artificial Intelligence, Vol.23, No.8, pp.1237-1246, 2010.

[13]. Qian H M, Mao Y B, Xiang W B, "Recognition of human activities using SVM multi-class classifier ", Pattern Recognition Letters, Vol.31, No.2, pp.100-111, 2010.

[14]. Yu S Q, Wang L, Huang K Q, et al, "Gait Analysis for Human Identification in Frequency Doinain", Image and Graphics, pp.282-285, 2004.

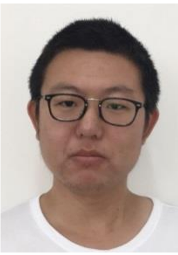
[15]. Cheng M H, Ho M F, Huang C L, "Gait analysis for humanidentification through manifold learning and HMM", Pattern Recognition,Vol.41, No.8, pp.2541-2553, 2008.

[16]. Bae J, Tomizuka M, "Gait phase analysis based on a Hidden Markov Model", Mechatronics, Vol.21, No.6, pp. 961-970, 2011.

[17]. Chen C H, Liang J M,Zhu X C, "Gait recognition based on improved dynamic Bayesian networks", Pattern Recognition,Vol.44,No.4, pp.988-995, 2011.

[18]. Kim D, Paik J, "Gait recognition using active shape model and motionprediction", Computer Vision lET, Vol.4, No.1, pp. 25 -36, 2010.

[19]. Liu Y Q, Wang X, "Human Gait Recognition for Multiple Views", Procedia Engineering, Vol.15, pp.1832-1836, 2011.
[20]. Yang X C, Zhou Y, Zhang T H, et al, "Gait recognition based on dynamic region analysis", Signal Processing, Vol.88, No.9, pp.2350-2356, 2008.
[21]. Lam T H W, Cheung K H, Liu J N K, "Gait flow image: A silhouette-based gait representation for human identification", Pattern Recognition, Vol.44, No.4, pp.973-987, 2011.
[22]. Kobayashi T, Otsu N, "Three-way auto-correlation approach to motion recognition", Pattern Recognition Letters, Vol.30, No.3, pp.212-221, 2009.
[23]. Babu R V, Ramakrishnan K R, "Recognition of human actions using motionhistory information exfracted from the compressed video", Image and VisionComputing, Vol.22, No.8, pp.597-607, 2004.
[24]. Nizami I F, Hong S, "Automatic gait recognition based on probabilistic approach", International Journal of Imaging Systems and Technology,Vol.20, No.4, pp.400-408, 2010.
[25]. Lee C S, Elgammal A, "Style adaptive contour tracking of human gait using explicit manifold models", Machine Vision and Applications, pp.1-18, 2010.
[26]. James J, Jeey E, Boyd, "Recognizing People by their gait : the shape of motion ", Journal of Computerion Reseach ,Vol.1, No.2, pp.2-32, 1998.



Wen Che
School of Electrical Engineering, Hebei University of Technology, Tianjin, China, master. His current research interests include pattern recognition and reactive power compensation.

Li Hua
School of Electrical Engineering, Hebei University of Technology Tianjin, China, associate professor and master supervisor. She is engaged in research on the pattern recognition and intelligent controls.

Zhou Chunlai
The School Of Information Engineering, The Communication University of China, Beijing, China. professor and doctoral supervisor. He is engaged in research on the pattern recognition and intelligent system.