Gait Recognition Method Based on Lower Leg under 45 Degree Viewing Angle of Video

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Abstract

The lower limbs of motion body contain rich identification of individuals in the process of walking. A gait recognition method based on ankle joint motion trajectory and bending angle is proposed. First it obtains lower limb joint points according to each part of the body and height proportion. It obtains the position coordinates of the toe by using skeleton algorithm. According to the position relationship between joint points and toe, we can extract bending angle information. The feature vector is made up of the relative velocity of ankle joint motion trajectory and the bending angle. Support vector machine (SVM) Classifier and the Nearest Neighbor (NN) Classifier are used for the gait classification. In addition, the most methods are tested experiment performance under 0 degree viewing angle. We use 45 degree viewing angle which has a larger view in our experiment. CASIA_A database is used to evaluate the performance of the proposed method. The experimental results demonstrate that the approach has an encouraging recognition performance.

Keywords: *motion object detection, relative velocity, bending angle, SVM, KNN*

1. Introduction

Biometric identification techniques allow the identification of a person according to some physiological or behavioral traits that are uniquely associated with him/her [1]. Nowadays techniques of the more mature and large-scale have iris, fingerprints, face, *etc*. The gait recognition is an emerging biometric identification technology, which tends to be realized by the walking posture. Compared with other biometric features, gait recognition has notable advantages such as long-range identification, non-contact, non-intrusive, good for hiding and the low resolution. Generally, gait recognition consists of three parts: gait detection, gait representation and gait identification.

The obvious action change of the walking process is mainly reflected: (1) The swing of the arms; (2) The large change of legs. Due to the impact of self-occlusion in silhouette sequences, arm motion become secondary factors. Segmented image of the upper part is not as well as lower limb because of the limitation of motion segmentation technology. So the legs become the research protagonist of gait motion characteristics. The change of leg joint points and feet swing become the focus.

In recent years, many researchers at home and abroad have many tentative works in the field of gait recognition. According to joint point change, the lower limbs of motion body contain rich identification information of individuals. Gait recognition based on lower limb motion arouse concern of researchers. Ying Zeng [3] extracted lower limb joint angles as gait recognition feature vector by positioning the joint points. Cunado [4] established leg model with two linkable pendulum and extracted frequency component from the curve of inclination angle as gait feature. Lei Geng [5] extracted gait feature information by tracking ankle motion trajectory.

Above methods obtained a better effect, but there are still some deficiencies: extraction feature information from the single aspect of the lower limb ignored the other aspects of human characteristics and reduce the gait recognition rate. Gait recognition method based on ankle joint trajectory and bending angle is proposed according to lower limb of motion body. First gait sequence images are pre-processed and background sub traction method accomplishes motion region segmentation. According to each part of the body and height proportion, it obtains lower limb joint points. It obtains the position coordinates of the toe by using skeletal processing. Through the ankle joint motion trajectory obtain relative velocity. According to the position relationship between joint points and toe extract, we can obtain bending angle information. The relative velocity and bending angle constitute the feature voter. Support vector machine (SVM) Classifier and the Nearest Neighbor (NN) Classifier are used for classification and identification. In addition, most of the methods are test experiment performance under 0 degree viewing angle. But it has a larger view field under 45 degree viewing angle. In our experiment, the 45 degree viewing angle of Database A is used to evaluate the performance of the proposed method. The experimental results demonstrate that the approach has an encouraging recognition performance. The combination of ankle joint motion trajectory and joint angle become the feature vector. It can reflects the time-space characteristic of gait motion and subtle changes of gait pattern.

2. Gait Feature Extraction

2.1. Motion Region Segmentation

1) Background Extraction: It constructs background image through time domain median filter method. The mid-value of multi-frame images is the background pixel value. It avoids abnormal pixel influenced background image. The method is as follows: There are n frames sequence. The same point pixel value of each frame constitute an array.

$$f(x,y) = [f_1(x,y), f_2(x,y), \ldots f_i(x,y), \ldots f_n(x,y)] \tag{1}$$

Using the equation (1) gets the background image.

$$B(x,y) = median(f(x,y)) \tag{2}$$

Where $median()$ is median function, $B(x,y)$ is the pixel value of background image.

2) Image Difference: Motion region is obtained through computing the difference of the current image and the background image. Hypothesis gray value of the nth frame image is $F_n(x,y)$, $B(x,y)$ is background model. $D_n(x,y)$ is the motion region ,which is defined as:

$$D_n(x,y) = |F_n(x,y) - B(x,y)| \tag{3}$$

3) Threshold Segmentation: Background image and motion region are separated through threshold segmentation. If the difference is greater than or equal to the threshold value and the pixels are motion region, otherwise they are the background pixels.

$$d(x,y)=\begin{cases}1, F(x,y)\ge T\\ 0, F(x,y)<T\end{cases} \quad (4)$$

Where $F(x,y)\ge T$ is motion region, $F(x,y)<T$ is background region.

4) Morphology Processing: The binary images may appear cavity and noise point. It not only remove cavity but also eliminate noise point by using the expansion and corrosion operation for binary images. As shown in Figure 1.

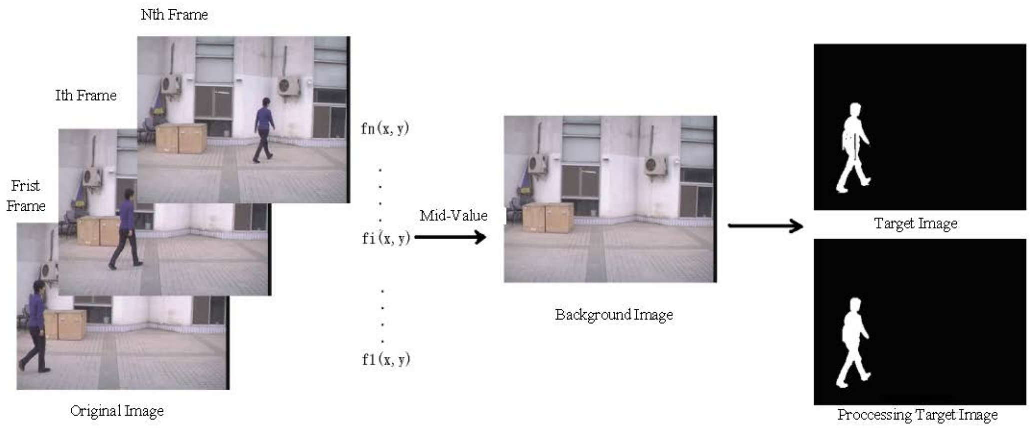


Figure 1. The Motion Region Segmentation

2.2. Joint Point Position Extraction

If human height is H, according to each part of the body and height proportion [6], we can determine the ordinate of lower limb. They are hip joint, knee joint and ankle joint respectively. $Y_1=0.47H, Y_2=0.715H, Y_3=0.961H$ .Human coordinate system is showed in Figure 2. (Annotation: Where coordinate origin is the upper left corner of human movement image, x axis is towards the right, y axis is towards the down).

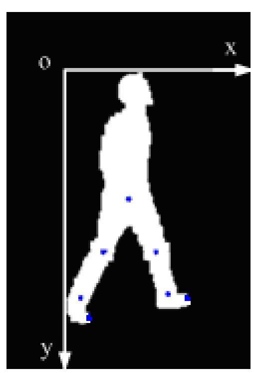


Figure 2. Coordinate System of Human

1) Knee Joint Point: The hip joint point determines the boundary between foreleg area and hind leg area. Scanning the two parts, the pixel values of the foreleg area and hind leg area are one respectively where is $Y_2=0.715H$. (The width of intervals are L_1 and L_2

respectively). The abscissa of foreleg area knee joint is $L_1/2$ of right endpoint of boundary. The abscissa of hind leg area knee joint is $L_2/2$ of left endpoint of boundary. If the knee joint point position appears overlap, the hip joint point is center of a circle. Knee joint point is a certain circular arc of the thigh length ($L_l = 0.25H$) as the radius. Leg width is $L_w = 0.1H$ at knee joint position. Left boundary point move right $0.05H$ and right boundary point move left $0.05H$ are knee joint position, as shown in Figure 3.

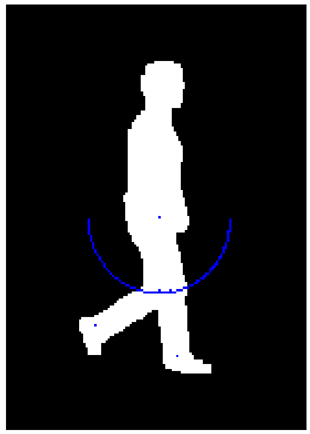


Figure 3. Folded Legs

2) Ankle Joint Point: The abscissas of two knees are scanning dividing lines. At $Y_3 = 0.961H$ scanning, seeking interval of pixel value 1. (The width of intervals are L_3 and L_4 respectively). The abscissa of foreleg area ankle joint is $L_3/2$ of front knee boundary right endpoint. The abscissa of hind leg area ankle joint is $L_4/2$ of back knee boundary left endpoint. If the ankle joint point appears overlap, it is processed by using the same way with the knee joint. After the above steps, you can determine the coordinates of the lower limb joint points, as shown in Figure 2.

2.3. Toe Coordinates Extraction

1) Skeletal processing: The body silhouette is segmented from the image and is converted into a skeletal model.

2) Seek foot position: It seeks the position of foot among skeletal model.

3) Label toe point: The angular point add to binary images' toe position. Then toe coordinate $p(x, y)$ can be approximately obtained.

After the above steps, we can get the toe coordinate. Figure 4 shows the schematic of the toe extraction. From left to right: (a) The binary image; (b) Skeletal model; (c) The angular point label toe position m, n.

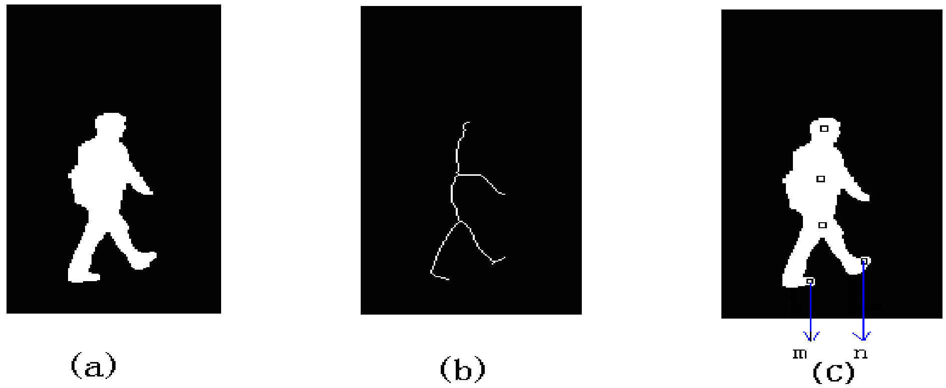


Figure 4. Toe Coordinates Extraction

2.4. Feature Extraction

1) Walk Path Extraction: Hough transform detects walk path as shown in Figure 5. Figure 5(a) is the superposition graph of different moments. Figure 5(b) detects walk path. Figure 5(c) is the straight path of walkers as shown in equation (5).

$$y = k * t + b \quad (5)$$

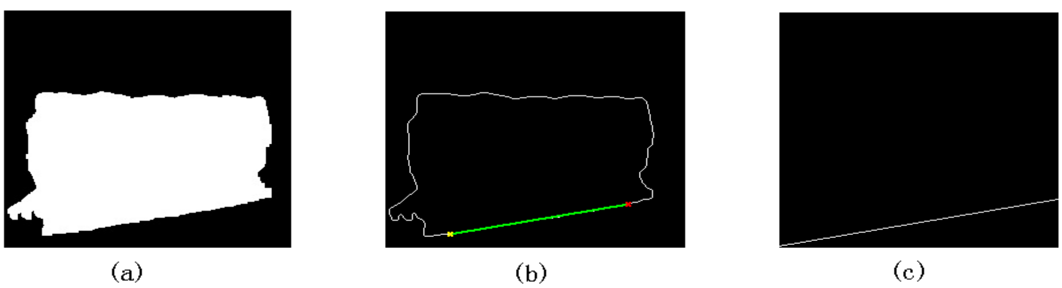


Figure 5. Detection the Straight Path of Walkers

It extracts each image ankle position coordinate $p_i(x, y)$ form trajectory curve to analyze and study. Motion trajectory of ankle as shown in Figure 6, where x-axis is abscissa, y-axis is ordinate. The curve above is the motion trajectory of ankle and the straight line below is the walk path.

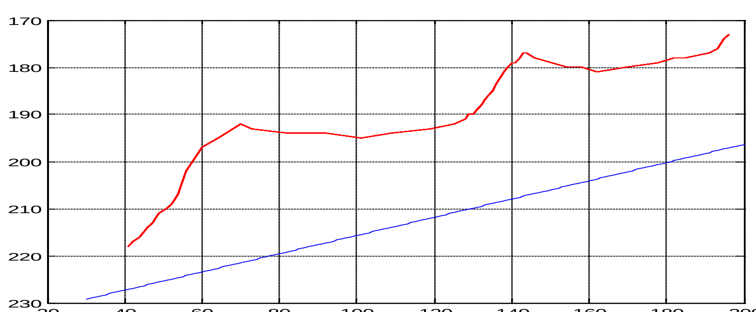


Figure 6. Motion Trajectory of Ankle

2) Relative Velocity Extraction: It gets relative distance between ankle motion trajectory and the walk path. Where $f(t)$ is the ankle motion trajectory. Relative distance as shown in equation (6).

$$D(t)=\frac{|k*t+b-f(t)|}{\sqrt{k^2+1}} \tag{6}$$

Where $t=0,1,2,\ldots n$
Dpference $D(t)$

$$V(t)=D(t+1)-D(t) \tag{7}$$

Where $V(t)$ is relative velocity of ankle.

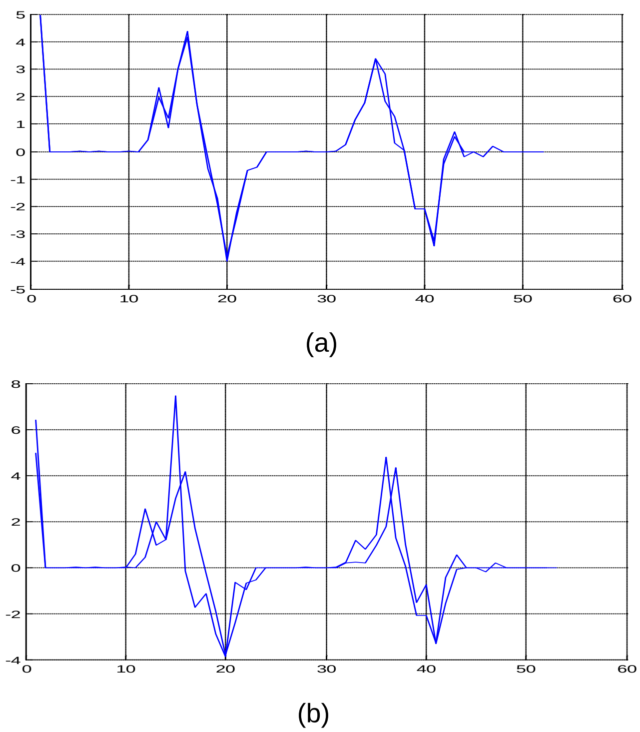


Figure 7. Relative Velocity of Ankle

Where Figure (a) is relative velocity of the same person, Figure (b) is relative velocity of the different person. Gait motion is the time-space behavior pattern. Effective gait descriptions not only contain the gait change with time but also describe gait spatial displacement variation information.

3) Bending Angle Extraction: It gets position coordinates of ankle joint A, knee joint B and toe C. Them connect to each position coordinates in turn form a triangle. Where θ is bending angle as shown in Figure 8.

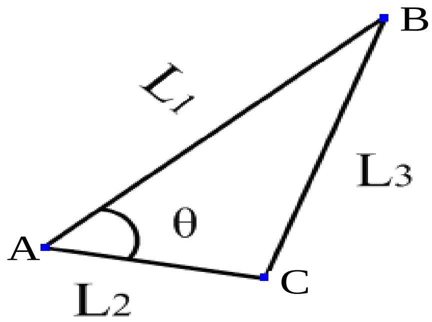


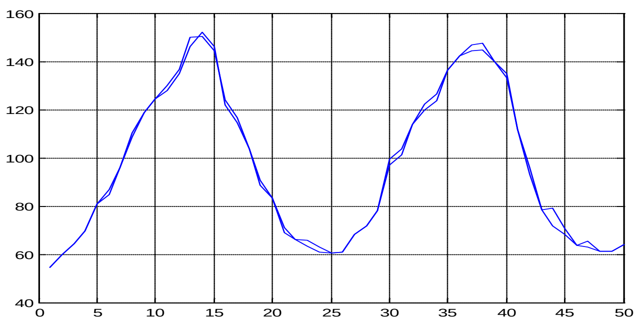
Figure 8. The Schematic of Bending Angle

It obtains the three vertices of the triangle. The equation (8) is the distance formula of side. (x, y) and (x', y') are the coordinates of two points. According to Euclid Distance Formula, it obtains the sides of triangle.

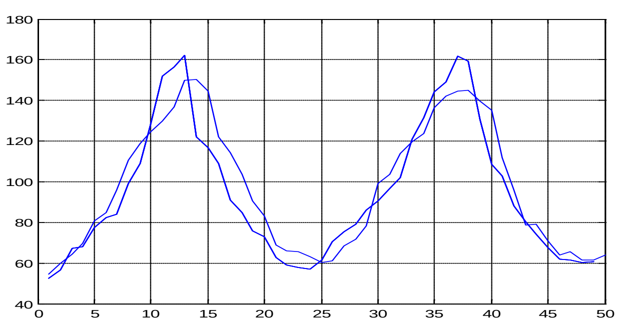
$$L = \sqrt{(x - x')^2 + (y - y')^2} \tag{8}$$

Cosine law obtain bending apngle θ.

$$\theta = \arccos\left(\frac{L_1^2 + L_2^2 - L_3^2}{2L_1L_2}\right) \tag{9}$$



(a)



(b)

Figure 9. The Angle Trajectory of the Walkers

The Figure (a) is the angle trajectory of the same person, Figure (b) is the angle trajectory of the different person. Angular variation is the vital parameters of gait motion. It can reflects the subtle changes of gait motion and contain rich gait pattern change information. In addition, this method does not need reducing-dimension processing, simple calculation and greatly reduce operation time.

In conclusion, relative velocity $V(t)$ and bending angle θ are feature vector in one complete cycle of image sequence.

3. Experimental

In our experiment, CASIA_A under 45 degree viewing angle database is used to evaluate the performance of the proposed method. The CASIA_A database [9] includes 20 subjects and four sequences for each viewing angle per subject, two sequences for one direction of walking and the other two sequences for reverse direction of walking.

In training process, segmentation gait image sequences obtain motion target. Each frame extracts gait feature. Gait features constitute feature vectors in one complete cycle of an image sequence. Finally the support vector machine (SVM) classifier and the Nearest Neighbor (NN) Classifier are used for classification and identification.

In testing process, we can extract feature vectors in the same way. Then the SVM classifier and NN classifier are used for classification.

3.1. Experimental Results

Table 1 shows the correct recognition rate of three classifiers: NN, KNN, and SVM. We can see from the table that the recognition performance of support vector machine (SVM) classifier is better than the other two classifiers. This shows that the mature and stable classifier will greatly improve the classification ability.

Table 1. The Correct Recognition Rate of the Different Classifiers

Classifier	CRR
NN	82.7%
3NN	87.8%
SVM	92.8%

3.2. Method Comparison

Table 2 is the recognition rate of the different methods. We can see from the table that the relative velocity and the bending angle not only improve the gait recognition rate but also show the effectiveness of the proposed algorithm.

Table 2. The Recognition Rate of the Different Methods

Method	CRR
Literature[3]	87.3%
Literature[4]	88.3%
In this paper	92.8%

The literature [3] extracted lower limb joint angles as gait feature. The literature [4] established leg model with two linkable pendulum and extracted frequency component from the curve of inclination angle as gait feature. This paper uses the relative velocity and bending angle as the feature vectors for gait classification. We can see from the Table 2 that recognition performance of this method is significantly higher than other methods. This method can reflect the time-domain characteristics of gait motion and subtle change of gait pattern.

4. Conclusion

This paper proposes a method which uses the relative velocity of ankle joint motion trajectory and the bending angle of foot relative to lower leg as gait feature. The support vector machine (SVM) classifier is used for classification. In order to verify the algorithm performance, Nearest Neighbor (NN) classifier and K-Nearest Neighbor (KNN) classifier are used for validation test. The experimental results demonstrate that the approach has an encouraging recognition performance. But this method has some limitations such as the small database and simple background etc. Future research will consider at in large scale database and complex background for gait recognition to improve the recognition rate and enhance the robustness.

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