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Walking Features Detection for Human Recognition

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ABSTRACT

Human recognition on camera is an interesting topic in computer vision. While fingerprint and face recognition have been become common, gait is considered as a new biometric feature for distance recognition. In this paper, we propose a gait recognition algorithm based on the knee angle, 2 feet distance, walking velocity and head direction of a person who appear in camera view on one gait cycle. The background subtraction method firstly use for binary moving object extraction and then base on it we continue detect the leg region, head region and get gait features (leg angle, leg swing amplitude). Another feature, walking speed, also can be detected after a gait cycle finished. And then, we compute the errors between calculated features and stored features for recognition. This method gives good results when we performed testing using indoor and outdoor landscape in both lateral, oblique view.

Key words: biometric, gait recognition, walking speed detection, leg features

1. INTRODUCTION

Nowadays, there are many kinds of demand is exposed to satisfy with the development of society. Automatically monitor a violate area, a station and alert when having an object intrudes this zone is an example. Building a timekeeping system not to need any timekeeper is also a necessary job. For constructing these kinds of system, a problem is proposed is how to detect and recognize the person waking in this violate zone. In computer vision there are many approaches are proposed to solve this problem. In the history of human recognition, finger print, iris, hand characteristics were introduced and become popular until now. After that, the using of face features for human recognition is applied. All of above method can give us the exactly recognition rate but exist an inconvenient is that these method must have the cooperation if the person who will be recognized. In this context, gait, one realm of biometric characteristic, outstanding as a new feature for distance human recognition. Gait is defined as the way or manner of a person walking on foot. And gait has more advantages than other features. The first thing we must mention is distance recognition. Not only we don't need any cooperation of analyzed person but also it is too difficult to conceal. Try to disguise, the individual will probably appear more suspicious. However, as any other features, gait also has some affect factors. Gait is the way walking on foot so if this person have any physical change (accident or disease), of course this feature will be affected. Stimulants such as drug and alcohol also influence to gait. One more important factor are clothes, same person wear different clothes will create a widely varying signature for an individual.

Assumptions

- The camera position was fixed throughout the video sequence.
- The moving objects are located sufficiently far from the camera.
- The moving object does not stand still for a

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long time.

1.1 Previous approaches for human gait recognition

There are many existing methods for human gait recognition:

Lee and Grimson [1] fit ellipses to seven rectangular subdivisions of the silhouette then compute four statistics (first and second-ordermoments) for each ellipse, and hence obtain 28 1D signals from the entire silhouette sequence. Finally, they use three different methods for mapping these signals to obtain a single feature vector for classification. M.S. Nixon, J.N. Carter, J.M. Nash, P.S. Huang, D. Cunado, and S.V. Stevenage [2] computing the width of the outer contour of the silhouette, the correlation between the probe silhouette image sequences and those in a data-set. Bobick and Johnson [3] compute body height, torso length, leg length, and step length for identification. Using a priori knowledge about body structure at the double support phase of walking (i.e., when the feet are maximally apart), they estimate these features as distances between fiducial points (namely, the midpoint and extreme) of the binary silhouette.. Cutler and Davis [4] used self-correlation of moving foreground objects to distinguish walking humans from other moving objects such as cars. In [5], an activity is represented by a set of pose and velocity vectors for the major body parts (hands, legs, and torso) and stored in a set of multidimensional hash tables. Bradski, G. and Davis, J [6] uses a simple method for representing motion in successively layered silhouettes that directly encode system time termed the timed Motion History Image (tMHI). [7] addresses the problem of learning and recognizing human and other biological movements in video sequences of an unconstrained environment. In Cutting and Kozlowski''s research [8], the sex of the walkers could be recognized from displays of point light sources mounted on people''s major joints with an average of 60~70% accuracy . They also found that lights on the upper body''s joints are more useful to recognize the movement. C. Yam, M. S. Nixon, and J. N. Carter use a bilateral and dynamically coupled oscillator is the key concept underlying this work [9]. [10] describe a new method for automatic gait recognition based on analysing the symmetry of human motion using the Generalised Symmetry Operator. This approach is reinforced by the psychologists' view that gait is a symmetrical pattern of motion and results show that gait can indeed be recognised by symmetry analysis. P.S. Huang, C.J. Harris, and M.S. Nixon, who use optical flow to derive a motion image sequence for a walk cycle. Principal components analysis is then applied to the binarized silhouette to derive what are called eigen gaits [11]. In [12] the approach implicitly captures biometric shape cues such as body height, width, and body-part proportions, as amount of arm swing. A. V. Nguyen and E. J. Lee [13] Proposed human recognition algorithm which is focused on the gait feature. However it has some weakness for recognition efficiency. To overcome this problem, we proposed new method for human recognition based on walking features such as head direction, distance of two foot, relative ratio of thigh as calf of leg and walking speed.

As we mentioned at disadvantages section, there are many factor effects to human gait. If we use the width of silhouette outer contour, it will be affected easily by those factors. Or when we use ellipse to fit to seven rectangular subdivisions of the silhouette, the result will be also depended on them. So, extract the features of legs is the good choice because it is rarely affected.

1.2 Organization of the paper

The rest of this paper is organized as follows: the first section for features extraction and recognition method. The next section is the performing and result of this method. Final section is conclusion and discussion.

2. WALKING FEATURES EXTRACTION AND RECOGNITION

The overview of our proposed algorithm is showed in the Fig 1. From the acquired image, we detect the moving object and then extracted feature from this result. After that, we make a feature vector which is used for recognition.

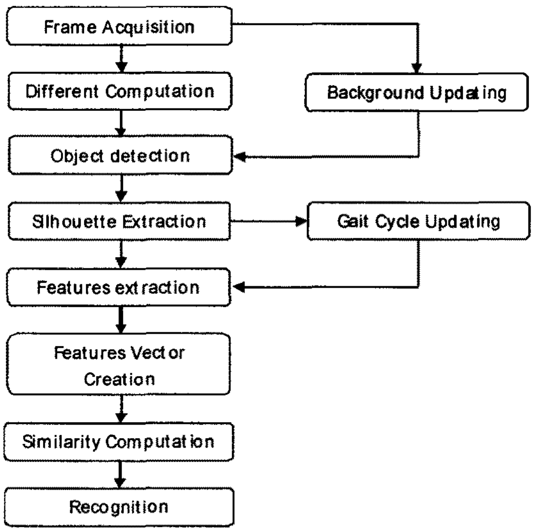


Fig 1. Overview of proposed algorithm.

2.1 Moving object detection method

2.1.1 Backgroun

From every frame of camera stream, we update the background image for subtraction process.

Background 1 Background 20 Background 80

Fig 2. Resulting of background updating process.

2.1.2 Walking object detection

Human tracking and extract the moving object in video stream is the pre-processing step in almost supervision system. In computer vision world, there are a lot of method are proposed to solve this problem. However, the object detection step in this algorithm is very important because all of the gait features are extracted from the detected object. The method we use here is the combination of comparison 2 continuous frames in video stream to detect the moving object and background subtraction for getting the fully silhouette. The background subtraction look like simple and popular in computer vision but it is the simplest and has been the most effectively performance for getting the moving object. In some other method, the background image must be created from several of image in video sequence firstly. This method can give a good result but it is difficult to apply in real-time system. Not only that method cans take a lot of time to estimate the background image but also the estimated background image may content noises, sometime. In our proposed algorithm, the difference of the current frame and the previous frame is computed firstly to detect the moving object position. The original image color is converted to HSL color space for computation.

$$diff = Get2ColorDifferent(F_{xy}^{i}, F_{xy}^{i-1}) \quad (1)$$

Where:

$diff$ stand for the different value of pixel value (HLS) of 2 continuous frames.

F_{xy}^{i}, F_{xy}^{i-1} stand for pixel value of frame i, i-1 at x and y location.

2.1.3 Silhouette extraction method

The silhouette extraction is described as in Fig3. After performing the background subtraction, we performed the Opening process and Connected Component Labeling (CCL) for smoothing and noise removal. The remain object is considered as the silhouette.

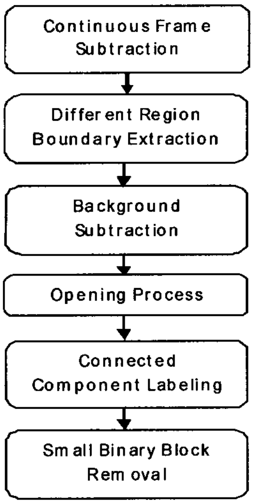


Fig 3. Silhouette extraction method.

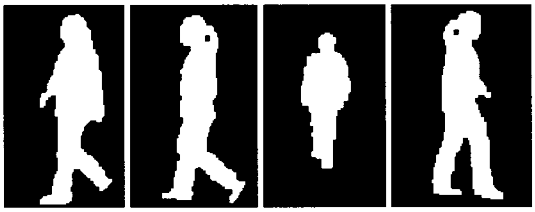


Fig 4. Resulting of silhouette extraction.

From the background image and the object boundary in above steps, we can us the image subtraction method to extract the silhouette.

$$f(x, y) = \begin{cases} \text{background, } \mathit{if\ abs}(I_{current}(x, y) - I_{backgraund}(x, y)) <= h \\ \text{foreground, } \mathit{otherwise} \end{cases}$$

Where :

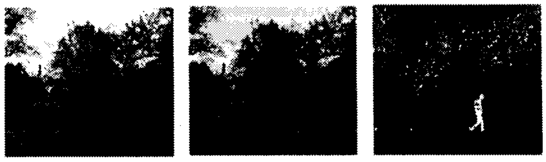
$f(x, y)$: pixel value at x, y.

$I_{current}(x, y)$: pixel value of current frame at x, y.

$I_{backgrounf}(x, y)$: pixel value of background image at x, y.

h : threshold

Based on a threshold, we can determine one pixel belongs to background or foreground. Fig 5 shows the result of image subtraction method. Image (a) is the current frame at time t, (b) is the estimated background and (c) is the output image.



(a) (b) (c)

Fig 5. Human detection using Image subtraction, (a) current image, (b) background image and (c) resulting human detection image.

However, after above process, there are a lot of pepper noises so we continue using the Opening Process for removing small noise. First, Erosion process is carried out to remove small noise and then use Dilation method to enlarge and connect small noise into larger object. Fig 6 illustrates for Erosion method while Fig 7 show the result of applying Opening Process.

But some small objects also exist so in the next step we must remove them. We used image labeling method to do this. After assigning a label (Fig 8) to each in image, we can remove small object by using the number of pixel as a threshold.

If the number of pixel of binary block is less than or equal the threshold, we will remove by assigning them belong to background (Fig 9).

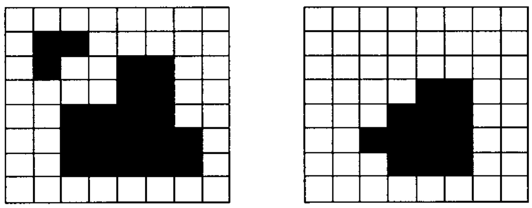
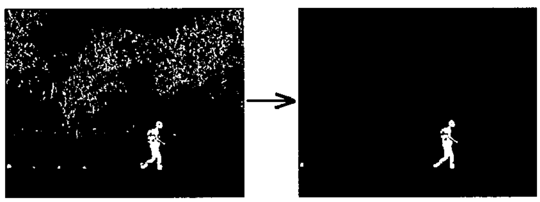


Fig 6. Erosion filter for removing small noises.



(a) (b)

Fig 7. Noise remove by filtering, (a) noisy image, (b) resulting image.

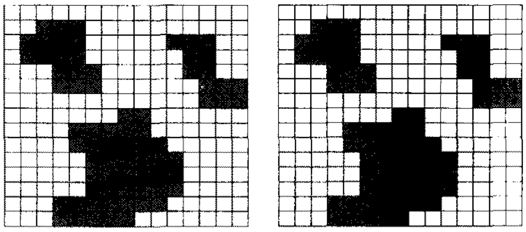
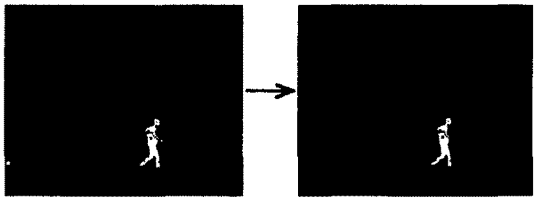


Fig 8. Labeling method for removing small object.



(a) (b)

Fig 9. Resulting of small object remove, (a) original image, (b) small object remove image.

2.1.4 Leg region extraction

After the silhouette is extracted, the leg region can be estimated by getting the 35% of object boundary as showed in Fig 10.

$$
\begin{aligned}
&LegRectTop = objRectTop + bjRectHeight*0.65 \\
&LegRectLeft = objRectLeft \qquad (2) \\
&LegRectRight = objRectRight \\
&LegRectBottom = objRectBottom
\end{aligned}
$$

Fig 10. Leg region extraction.

2.2 Walking features detection

And now we will describe how the gait features are extracted from the detected object in previous section. At first, all of gait features are listed and the detail of how to detect these features will be described in next step. There are 4 main features will be used:

+ Head direction.
+ Ratio of thigh and calf of leg.
+ Maximum 2 feet distance.
+ Minimum and maximum angle at knee.
+ Walking velocity.

2.2.1 Minimum and maximum knee angle detection

One possible signature for gait of a person is to use the angle of knee over the video sequence. To compute this feature, the getting leg skeleton process need to be carried out first. As in Figure 11, when three points for each leg {L1, L2, L3} for left leg and {R1, R2, R3} for right leg as in above figure are extracted, the angle at L2, R2 and the distance of L3, R3 can be easily calculated.

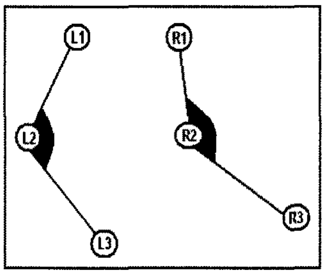


Fig 11. Feature point for each leg.

2.2.2 Walking velocity

Based on the distance of R2, L2 we can determine the end and start time of a gait cycle. When the distance of L2, R2 achieves the maximum values, we mark this time is t_i. When the distance of two knee is max at the second time, the old gait cycle has finished and the new one starts. Based on this, the gait cycle speed can be computed by getting the number of frame between t_i and t_{i+2} time for one cycle. And at the end of cycle we also find out the minimum and maximum angle for each leg.

$$walking\_velocity = \frac{number\_of\_frame}{1\_gait\_cycle} \qquad (3)$$

2.2.3 Maximum 2 feet distance and ratio of thigh and calf of leg

During the interval of gait cycle, we also calculate the distance of 2 feet(L3 and R3 as in Figure 11). When a cycle finished, we select the maximum value which are used for recognition process. However, because the size of current and database objects is different, so we use the ratio of this distance and object boundary height for exactly recognition.

Also base on these feature points, we can calculate the ratio L1L2 to L2L3(for left leg) and R1R2 to R2R3(for right leg)

2.2.4 Head direction detection

For calculating this feature, we use the center of gravity of the head region. From the extracted silhouette, it is easy for getting the binary head region. After that, the head polygon boundary is extracted by using the following method:

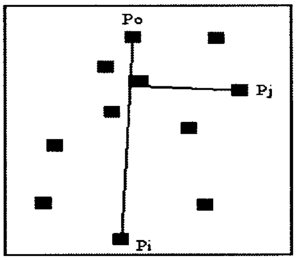


Fig 12. Polygon detection method.

Step1: Select Po as the starting vertex, Po -> P_{head}\{\}
Step2: Find Pi which has the maximum distance to Po, Pi-> P_{head}\{\}.
Step3: Find Pj which has the max distance to PoPi, Pj -> P_{head}\{\}.
Step4: Select Pj as the starting vertex.
Step5: Return to Step2.

After having the head boundary rectangle we continue calculate the coordinate of centroid point by using these functions.

$$A = \frac{1}{2}\sum_{i=0}^{N-1}(x_i y_{i+1} - x_{i+1} y_i)$$
$$c_x = \frac{1}{6A}\sum_{i=0}^{N-1}(x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \qquad (4)$$
$$c_y = \frac{1}{6A}\sum_{i=0}^{N-1}(y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i)$$

In above equation, we denote A is the area of polygon, N is the number of vertex, x_i, y_i are coordinate of each vertex, c_x, c_y are the coordinate of centroid point. And the body centroid is also calculated using the same method. After both of them are extracted, we can calculate the direction of head when this person is walking. When a person is walking, the silhouette width and height will change frame by frame. When two feet distance reaches to maximum value or overlap, both with and height of this person are also affected. Moreover, because the variant of the ratio of width and height of everyone is different so we can use it for human recognition.

3. EXPERIMENTAL RESULTS

The performance of the implemented algorithm has been tested in total 70 input objects include indoor and outdoor. For testing, we used some video of CMU database, which contain the lateral and oblique walking person in the complex background, and some captured video in our database.

The result is divided into 2 phase: the first for silhouette extraction correct rate and the second for recognition. Table 1, 2 show the accuracy of silhouette extraction and leg feature recognition, respectively.

Table1. Silhouette extraction accuracy

Number of objects	Detected objects	Rate
70	67	96%

Table 2. Leg feature recognition accuracy

Camera view	Number of objects	Recognized objects	Rate
Lateral	24	23	96%
Oblique	43	41	91%

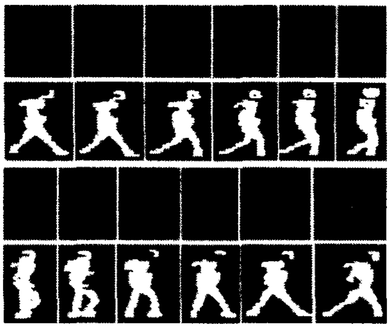


Fig 13. Silhouette extraction on one gait cycle.

Fig. 13 shows the leg feature extraction result in the outdoor and indoor environment. In the following Fig.13, in the outdoor environment, we show the testing result of 4 objects in 2 difference positions on complex background from (a1, a2) to (f1, f2). And also, in the indoor condition, we used our database for testing and show a result of one object with 2 positions.

4. DISCUSSION AND FUTURE WORK

As we mentioned at the previous part, gait will be heavily affected by the clothes that analyzed

Table 3. Leg angle detection results

Picture	Right Knee Angle	Left Knee Angle
a1	105^0	160^0
b1	175^0	178^0
c1	135^0	140^0
d1	120^0	175^0
e1	125^0	180^0
f1	145^0	172
g1	175^0	158^0
h1	162^0	180^0

Table 4. Leg speed, swing amplitude detection results

Image	Speed (frame/cycle)	Swing amplitude (2 legs distance / object height)
a1, b1	22	27%
c1, d1	21	19%
e1, f1	50	28%
g1, h1	35	21%

Table 5. Proposed algorithm accuracy

Total objects	Recognized objects	Correct rate
70	62	88,6%

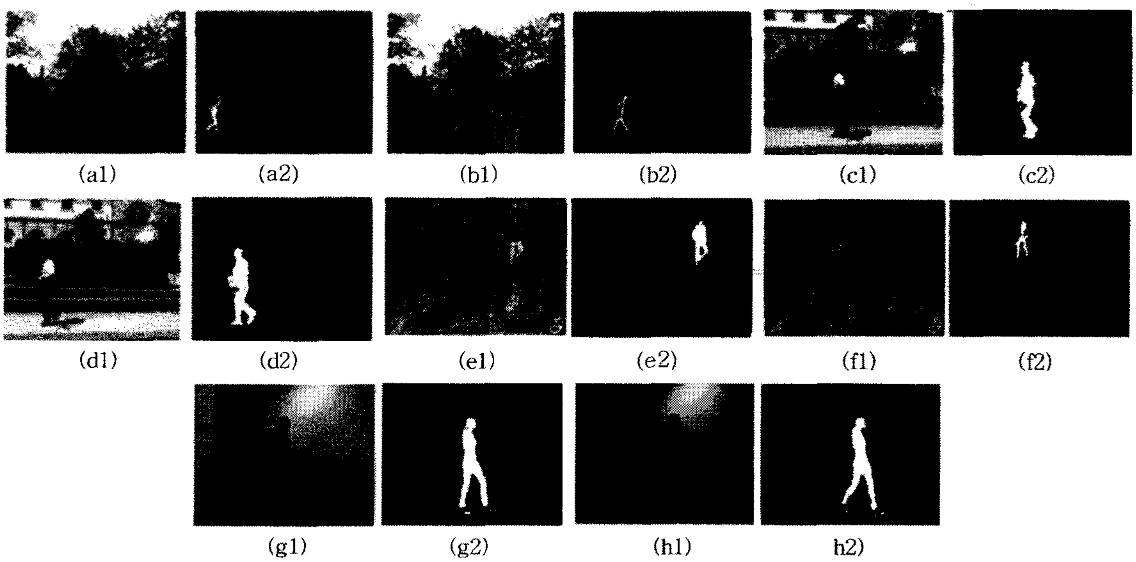


Fig 14. Leg feature extraction in outdoor and indoor condition, (a1), (b1), (c2), (d1), (e1), (f1), (g1), (h1) are source images, and (a2), (b2), (c2), (d2), (e2), (f2), (g2), (h2) are extracted feature images base on the silhouette in outdoor and indoor condition..

person is wearing and some other factors. If the analyzed person is wearing a rain coat or an over-coat, our algorithm would give a not good result because we can get good feature of the legs. That is the weak point of our algorithm and also for all of the gait recognition method.

So for having high accuracy recognition of an individual with the weak point list in introduction part we should have multiple representation of a person. This algorithm is good for human gait recognition and can be used to combine with face recognition for getting the good result for human recognition.

In the future, we will continue developing our algorithm for improving the recognition rate and then integrate with another biometric signature for human recognition.

5. CONCLUSION

In this paper, we proposed gait recognition algorithm based on the joint angle, leg swing amplitude and the speed of a person who appear in camera view on one gait cycle. The background subtraction method firstly use for binary moving object extraction and then base on it we detect the leg region and get gait features. Another feature, walking speed, also can be detected after a gait cycle finished. In the experimental results, the proposed algorithm shows good recognition accuracy in the outdoor and indoor environment.

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