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Gait Recognition System: Bundle Rectangle Approach

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***Abstract*—**Biometrics methods include recognition techniques such as fingerprint, iris, hand geometry, voice, face, ears and gait. The gait recognition approach has some advantages, for example it does not need the prior concern of the observed subject and it can record many biometric features in order to make deeper analysis, but most of the research proposals use high computational cost. This paper shows a gait recognition system with feature subtraction on a bundle rectangle drawn over the observed person. Statistical results within a database of 500 videos are shown.

***Keywords*—**Autentication, Biometrics, Gait Recognition, Human Identification, Security.

I. Introduction

AN authentication system can use a wide variety of methods for people identification. According to the application and security policies, those methods could include external or biometric authentication but when individual identification is needed, external authentication is not the best option, because a person could gain access not for being the correct person but for having the correct identifier system.

Individual biometrical identification system is achieved with methods such as fingerprints, face, hand geometry, iris, voice, signature, and gait [1], but all of them, excluding gait, needs to be captured only by physical contact or at a close distance from the recording sensor [2].

Human gait recognition system has many advantages as biometric option, such as being an unobtrusive technology, can be captured at a distance, it does not require the consent of the observed individual and it is very difficult to steal, fake or hide.

The study of gait began as a medical research [3, 4] with applications on kinesiology, sports, rehabilitation and malformation detection [5]. Other researches documents have been focused on biomechanical and robotics, not only for human gait analysis but also for animal gait [6]. The proposed research is intended for real-time identifying individuals on security applications. [8~29]

The proposed human gait recognition system is represented by the blocks diagram showed in Fig. 1. Once the individual is captured by a conventional camera, the background is subtracted, the individual features are extracted, and the individual is finally recognized by comparing the obtained characteristics with the ones previously stored in the database.

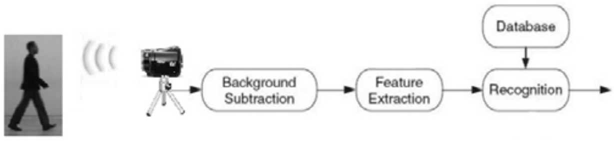


Fig. 1 Human Gait Recognition System

The background subtraction process is showed in the second part of the paper. The third section shows the feature extraction process with the variables captured over the bundle rectangle. The database and its characteristics are explained in the fourth part of the paper. The recognition algorithm is given in the fifth section. Finally, during the sixth segment, the recognition results are shown and analyzed.

II. Background Subtraction

The background subtraction is achieved with two images of the same person delayed 10ms from each other. The absolute difference between these images gets into a threshold operation where the brightness threshold θ in an image *–img[m,n]–* is chosen and then applied with the next condition [7]:

$$\left\{\begin{matrix} img[m,n] \geq \theta & img[m,n] = person = 1 \\ img[m,n] \langle \theta & img[m,n] = background = 0 \end{matrix}\right\}.$$

An example of the image brightness histogram is showed in the fig. 2.

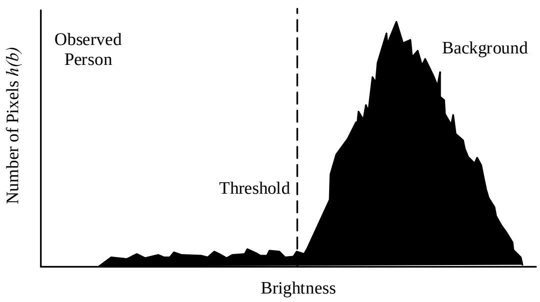


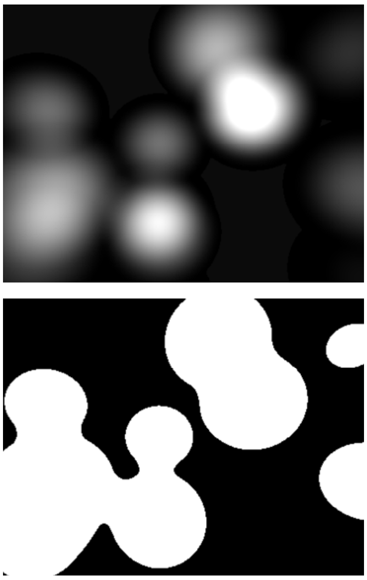
Fig. 2 Image brightness histogram

The image histogram is taken on the gray value of the image and in order to translate into a zero-phase smoothing we can use the next equation [7].

$$h_{smooth}[b] = \frac{1}{W} \sum_{w=-(W-1)/2}^{(W-1)/2} h_{raw}[b-w]$$

A single median filter is applied in order to avoid pepper noise on the video.

The resulting image is cut into fragments that are joined with a technique called blob construction. The technique achieves a reconstruction of the observed person by joining near pixels as it can be observed in the Fig. 3.



a)

b)

Fig. 3 a) Image before blob detection, b) Image afterer blob detection

The smaller blobs are eliminated if they are separated from the observed person.

III. Feature Extraction

Based on the extracted silhouette with the background subtraction process, a bundle rectangle is drawn. Reference points are located at the outermost points of the rectangle as can be seen in Fig. 4.

Fig. 4 Bundle Rectangle

Upper left and right points, and bottom left and right points can provide their position *(x, y)* given in pixels. At each time instant *t*, both left points –*LP*– and right points –*RP*– share the same position on axis x, as upper points –*UP*– and bottom points –*BP*– do on axis y.

The gathered information is used to analyze the gait cycle through the rectangle's behavior. Gait features are extracted in aspects such as rectangle's height, width, area, diagonal's angle and frequency.

A. Bundle Rectangle Mean Height

Bundle rectangle height behavior is determined by gait cycle as shown in Fig. 5.

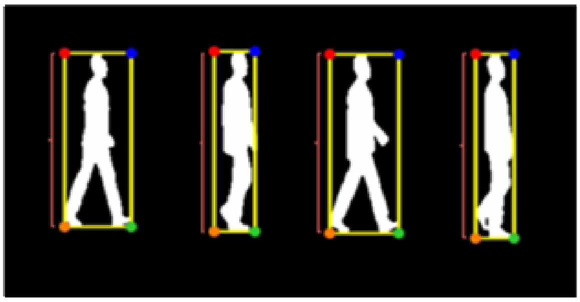


Fig. 5 Bundle Rectangle Height

Bundle rectangle mean height –*H*– is the representative height value for a person. It is obtained by averaging the difference between upper and bottom points on axis *y* at each time instant *t*, as given by

$$H = \frac{\sum_{i=1}^{N_H} [y_{UP}(t) - y_{BP}(t)]_i}{N_H}, \qquad (1)$$

where N_H represents the total quantity of data gathered for height feature. The measurement values not only specify the person height but also the change on tiptoe position in the gait cycle.

B. Bundle Rectangle Mean Width

Bundle rectangle width behavior is determined by gait cycle as shown in Fig. 6.

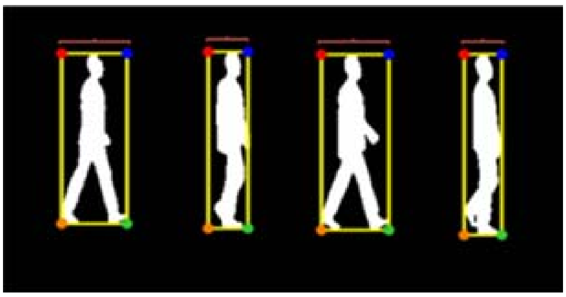


Fig. 6 Bundle Rectangle Width

Bundle rectangle mean width –*W*– is the representative width value for a person. It is obtained by averaging the difference between right and left points on axis *x* at each time instant *t*, as given by

$$W = \frac{\sum_{i=1}^{N_W} \left[x_{RP}(t) - x_{LP}(t) \right]_i}{N_W}, \quad (2)$$

where N_W represents the total quantity of data gathered for width feature. The width gives a measure of hands and legs rhythm with their variation.

C. Bundle Rectangle Mean Area

Bundle rectangle area behavior is determined by gait cycle as shown in Fig. 7.

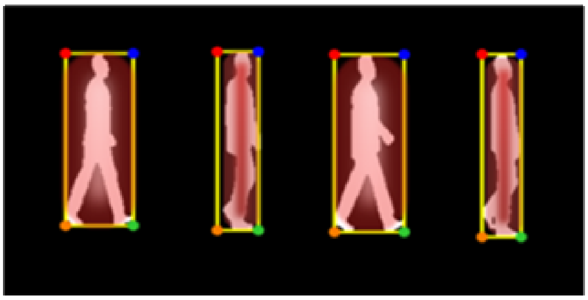


Fig. 7 Bundle Rectangle Area

Bundle rectangle mean area –*A*– is the representative area value for a person. It is obtained by averaging the multiplying between bundle rectangle height and width at each time instant *t*, as given by

$$A = \frac{\sum_{i=1}^{N_A} \left[H(t) \cdot W(t) \right]_i}{N_A}, \quad (3)$$

where N_A represents the total quantity of data gathered for area feature.

D. Bundle Rectangle's Diagonal Mean Angle

Bundle rectangle's diagonal angle varies in a gait cycle as shown in Fig. 8.

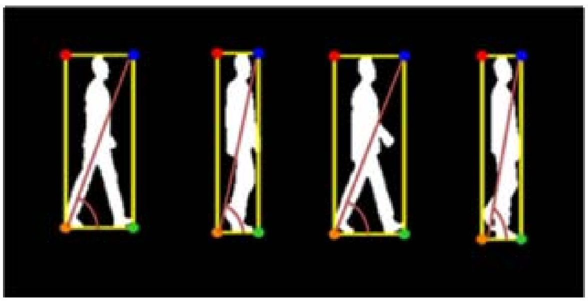


Fig. 8 Bundle Rectangle's Diagonal Angle

Bundle Rectangle's diagonal mean angle –*α*– is the representative diagonal angle value for a person. It is obtained by averaging the difference, in degrees, between axis *x* and the diagonal shown in Fig. 8 at each time instant *t*, as given by

$$\alpha = \frac{\sum_{i=1}^{N_\alpha} \left[\tan^{-1}\left(\frac{H(t)}{W(t)} \right) \right]_i}{N_\alpha}, \quad (4)$$

where N_α represents the total quantity of data gathered for diagonal angle feature.

E. Bundle Rectangle's Total Spectral Power

The rectangle area behavior in the frequency domain –*A(f)*– is calculated by applying the fast finite Fourier transform to the gathered rectangle area data –*A(t)*– as given by

$$A(f) = \sum_{t=0}^{N_A - 1} A(t) \cdot e^{-2\pi \frac{t \cdot f}{N_A} i}, \quad (5)$$

where N_A represents the total quantity of data gathered for area in the time domain.

The bundle rectangle's total spectral power –*P*– is represented by the sum of the data obtained by (5), and is given by

$$P = \sum_{f=1}^{N_f} A(f), \quad (6)$$

where N_f represents the total quantity of data calculated for area in the frequency domain.

IV. Gait Recognition System Database

The extracted gait features of height, width, area, diagonal angle and total spectral power can be used to build an initial gait-based identification arrange for each taken video.

For research proposes, five eight-second-length videos were taken for each individual. In fact, the gathering of these five videos provides a general overview of the person gait behavior. The parameters were acquired from 100 videos of 100 people; the next 400 videos of the same 100 people were used to identify the subjects.

The videos can be downloaded at the website, http://gissic.umng.edu.co. It is possible to get the videos after the background subtraction process by signing out a copyright agreement.

As essential part of the database generation process it is necessary to establish a range for each feature where the obtained values of height, width, area, diagonal angle and total spectral power match for the same person. This range is calculated from the stored values in the acquisition process, by calculating the half part of subtracting the smallest observation from the greatest, for each feature.

The final identification arrange for a person is given by averaging the values for each feature and establishing each feature range (see Table I).

TABLE I. INDIVIDUAL IDENTIFICATION ARRANGE

Feature	Individual Identification	
	Feature Identification Value	**Feature Range Value**
Height	$H_{value} = \frac{\sum_{i=1}^{N} H_i}{N}$	$H_{range} = \frac{H_{\max} - H_{\min}}{2}$
Width	$W_{value} = \frac{\sum_{i=1}^{N} W_i}{N}$	$W_{range} = \frac{W_{\max} - W_{\min}}{2}$
Area	$A_{value} = \frac{\sum_{i=1}^{N} A_i}{N}$	$A_{range} = \frac{A_{\max} - A_{\min}}{2}$
Diagonal Angle	$\alpha_{value} = \frac{\sum_{i=1}^{N} \alpha_i}{N}$	$\alpha_{range} = \frac{\alpha_{\max} - \alpha_{\min}}{2}$
Total Spectral Power	$P_{value} = \frac{\sum_{i=1}^{N} P_i}{N}$	$P_{range} = \frac{P_{\max} - P_{\min}}{2}$

N is the total number of videos taken for each individual

The gait recognition system database is built by arranging two or more individual identification arranges

V. GAIT RECOGNITION

The gait features such as height, width, area, diagonal angle and total spectral power of a recognizable individual, present in the database, are arranged as *H, W, A, α* and *P*. The five measured features are compared by the recognition algorithm with each individual identification ranges stored in the database. The individual, who is present in all the feature matching lists, is considered as the recognized person.

A. Height Recognition

The value given by H matches with the stored height data of the person i when

$$\left[H_{value} - H_{range}\right]_i \le H \le \left[H_{value} + H_{range}\right]_i. \qquad (7)$$

A list of matching individuals for height feature is generated.

B. Width Recognition

The value given by W matches with the stored width data of the person i when

$$\left[W_{value} - W_{range}\right]_i \le W \le \left[W_{value} + W_{range}\right]_i. \qquad (8)$$

A list of matching individuals for width feature is generated.

C. Area Recognition

The value given by A matches with the stored height data of the person i when

$$\left[A_{value} - A_{range}\right]_i \le A \le \left[A_{value} + A_{range}\right]_i. \qquad (9)$$

A list of matching individuals for area feature is generated.

D. Angle Recognition

The value given by α matches with the stored angle data of the person i when

$$\left[\alpha_{value} - \alpha_{range}\right]_i \le \alpha \le \left[\alpha_{value} + \alpha_{range}\right]_i. \qquad (10)$$

A list of matching individuals for diagonal angle feature is generated.

E. Total Spectral Power Recognition

The value given by P matches with the stored height data of the person i when

$$\left[P_{value} - P_{range}\right]_i \le P \le \left[P_{value} + P_{range}\right]_i. \qquad (11)$$

A list of matching individuals for total spectral power feature is generated.

VI. RESULTS

The bundle rectangle-based gait recognition system previously described was tested with 500 videos of 100 individuals. The biometric system recognition reliability –*R*– is statistically analyzed for each extracted feature and for the system as a whole, by evaluating the result given by

$$R = 100\% - FRR - FAR, \qquad (12)$$

where false reject rate –*FRR*– represents the statistical probability that an imposter is recognized as an enrolled person and false accept rate –*FAR*– is given by the statistical probability that the system fails to recognize an enrolled person. While *FRR* and *FAR* tend to zero the gait-based recognition system is 100% reliable.

A. Height Feature Results

The results statistical analysis shows that height feature presents a recognition reliability between 82% and 100% as shown in Fig. 9.

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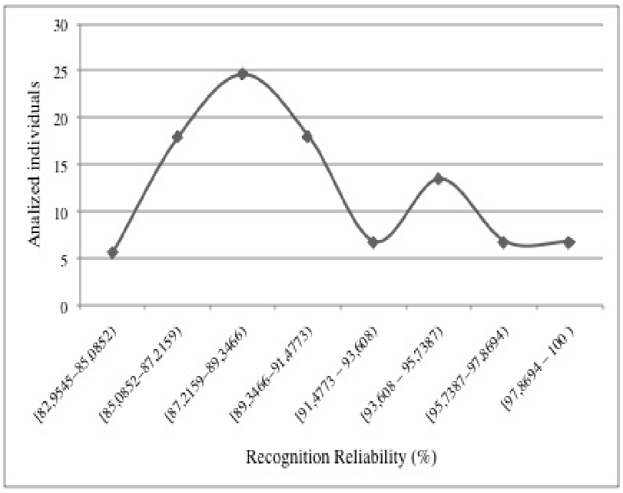

Fig. 9 Height Feature Recognition Reliability

One quarter of the analyzed individuals were height-based recognized with 88% reliability. Almost the 60% of the people were identified with recognition reliability between 85% and 91%.

B. Width Feature Results

The width feature results statistical analysis shows that width feature presents recognition reliability between 67% and 100% as shown in Fig. 10.

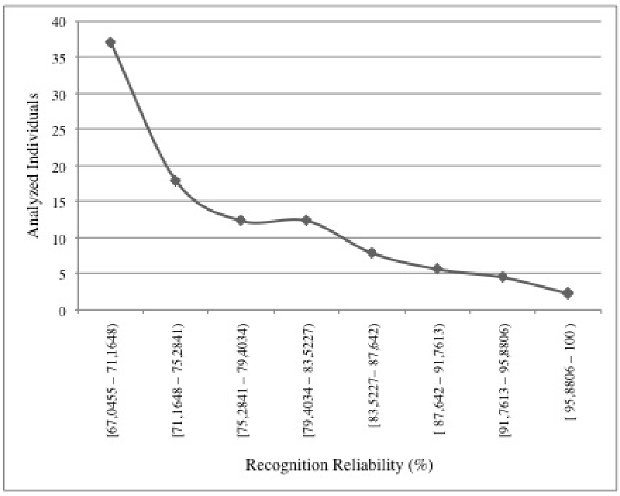

Fig. 10 Width Feature Recognirion Reliability

More than 33% of the analyzed individuals were width-based recognized with 70% reliability. Almost the 80% of the people were identified with recognition reliability between 67% and 83%.

C. Area Feature Results

The results statistical analysis shows that area feature presents recognition reliability between 73% and 100% as shown in Fig. 11.

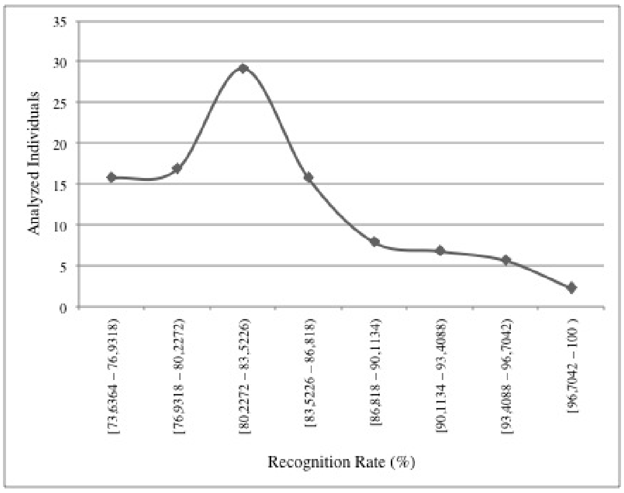

Fig. 11 Area Feature Recognition Reliability

Almost one third of the analyzed individuals were area-based recognized with 82% reliability. 60% of the people were identified with a recognition reliability between 76% and 83%.

D. Diagonal Angle Feature Results

The results statistical analysis shows that angle feature presents a recognition reliability between 60% and 95% as shown in Fig. 12.

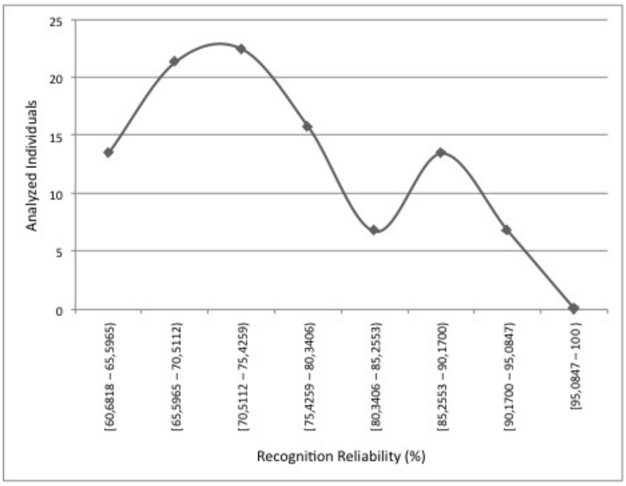

Fig. 12 Diagonal Angle Feature Recognition Reliability

Almost one fourth of the analyzed individuals were diagonal angle-based recognized with 73% reliability. 27% of the people were identified with a recognition reliability between 80% and 95%.

E. Total Spectral Power Feature Results

The total spectral power feature results statistical analysis shows that total spectral power feature presents a recognition reliability between 73% and 100% as shown in Fig. 13.

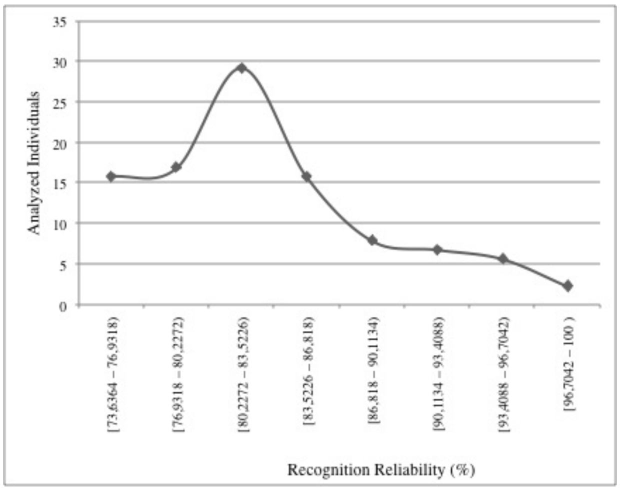

Fig. 13 Total Spectral Power Feature Recognition Reliability

Almost one third of the analyzed individuals were spectral power-based recognized with 82% reliability. 60% of the people were identified with a recognition reliability between 76% and 83%.

F. Gait Recognition System Results

In average, the height, width, area, diagonal angle and total spectral power feature recognition reliabilities behave as shown in Fig. 14.

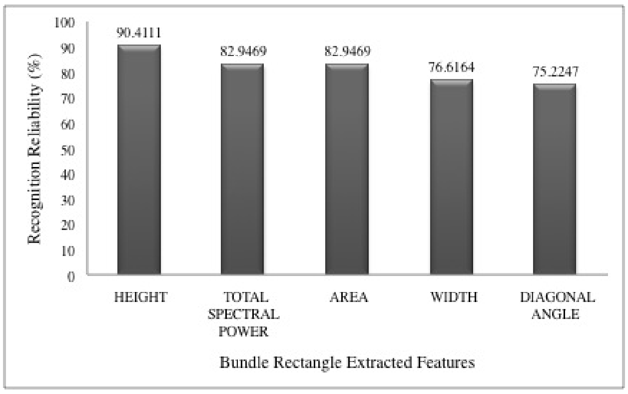

Fig. 14 Features Reliability

The sequential organization of the features as given in Fig. 14 improves the gait-based recognition algorithm performance.

The gait-based recognition system results statistical analysis shows that the system as a whole presents a recognition reliability between 95% and 100% as shown in Fig. 15.

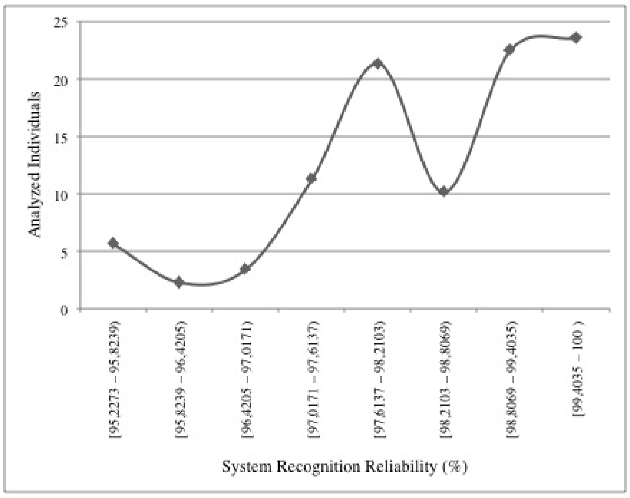

Fig. 15 Features Reliability

91% of the analyzed individuals were identified with a recognition reliability between 97% and 100%. 45% of the people were recognized with reliability between 98.8% and 100% and 24% of the analyzed individuals were 100% identified.

VII. Discussion and Conclusion

The results showed low recognition reliabilities when the features are separately analyzed. However, the system reliability severally increases by analyzing the recognition system as a whole. The reliability of the proposed human gait recognition system based on the simple extracted features over a bundle rectangle with the analysis of five classifiers such as height, width, area, diagonal's angle and total spectral power is near to 98.6%. The improvement of the system reliability consists in extracting and analyzing new features with mathematical transformations.

The proposed feature extraction main advantage is to reduce the computational cost in the analysis and in the database search time, but it's necessary to study cases where people are carrying objects such as bags or caps.

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