Person Identification using Shadow Analysis

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We introduce a novel person identification method for a surveillance system of much wider area than conventional systems using CCTV cameras. In the proposed system, we install cameras to rooftops of buildings or a low altitude airship, and identify people by gait features extracted from shadows, which are projected on the ground by the sun in the daytime or lights in the evening. Figure 1 shows an image above a city; what appears to be the shape of a human body is in fact the shape of its shadow, a body projection. Shadows offer the connecting link between aerial observation and gait/biometrics/gesture and behavior classification.

Since conventional systems extract gait features from actual body area, the correct classification ratio is reduced due to the lack of information of body area, in case that images are captured by overhead cameras. On the other hand, the proposed system enables to identify people by gait features which are extracted from shadows projected on the ground, even if images are captured by overhead cameras. In the proposed system, shadow areas projected on the ground are extracted automatically from captured images, and then analyze dynamics of shadow areas by the spherical harmonics. The following offers the summary of each process.

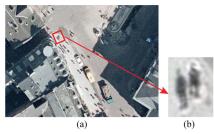


Figure 1: (a) Remote sensing imagery (Google [1]), (b) magnification of smaller window. What looks like humans are shadows.

Segmentation To extract shadow silhouettes from captured images, firstly a background subtraction is used. Figure 2 (b) shows an example of extracted silhouettes, from the original image shown in Fig. 2 (a). Then we separate body area and shadow area from silhouette images automatically. The method to separate these areas is based on a histogram of an average image from sequential silhouette images. Since foot touching the ground remains in the same pixel of images for several frames, the value of this pixel in the average image is bigger than other pixels. The proposed method separate shadow area and body area by utilizing this information as shown in Fig. 3.

Extraction of gait features Dynamic features of gait sequence are obtained as follows: in each row of the image I(x,y,t) the largest distance H(y,t), which we name here "gait stripe", is determined as the absolute value of the distance between extremities of this shape, illustrated in Fig. 4 as a horizontal stripe measured from left to right. Then we apply spherical harmonics transforms [2] to analyze shadow dynamics.

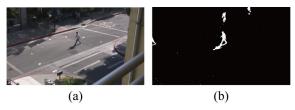


Figure 2: (a) A sample image, (b) its extracted target region.

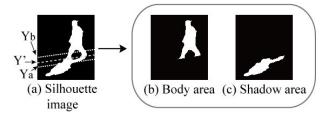


Figure 3: Examples of body and shadow separation.



Figure 4: Determination of H(y,t).

In the experiments, we used a shadow gait database collected in [4]. The database contains raw image sequences, and Fig. 2 (a) shows an example entry from the database. It contains 20 video sequences, which contain 5 different subjects with 4 sequences for every subject. Moreover, we used the leave-one-out cross validation to estimate the classification error rate (CCR). In the first experiment, we extracted gait features from extracted shadow area for classification and compared the proposed method with conventional methods, which are based on 1D Fourier Transform (1D DFT) [5], affine moment invariants (AMIs) [3], and 2D Fourier Transform (2D DFT). Table 1 shows the results, and from these results, the CCR by the proposed method (Table 1 (4)) is the highest compared with those by both conventional methods.

When oblique images are captured as shown in Fig. 2 (a), the shadow area and the body area can be considered as images captured from different cameras placed at different positions. So in case that gait features can be extracted from both areas, the CCR becomes high by using features from both areas. In the last experiment, we extracted gait features from these two areas, and the CCR was $100\,\%$.

Table 1: Comparison of the proposed method and conventional methods.

	The number of	Correct classification
	features	rate [%]
(1) 1D DFT[5]	Image resolution×3	85
(2) AMIs[3]	6	70
(3) 2D DFT	Image resolution	65
(4) The proposed method	49	95

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