Shadow Type Identification for Gait Recognition using Shadows

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Abstract

Using features acquired from the shadow cast by a walking person can be an alternative for gait recognition whenever the person's body is occluded, such as when capturing images from an overhead position. However, the shadow, depending on the light source characteristics, can be cast as a blob with no distinguishing characteristics. Most state-of-the-art methods fail in the presence of such "diffused" shadows. Thus, this paper presents a novel method to identify the type of shadow cast by a person. The proposed method generates a histogram of the intensity ratio between foreground and background areas, whose analysis allows identifying the type of shadow cast by the person. The proposed method is very promising, achieving a 90% correct shadow type identification with the dataset tested.

1 Introduction

Gait is a biometric trait that describes the way a person walks. It is a cyclic combination of movements that results in human locomotion [1]. Thus, in a surveillance environment, gait becomes difficult to hide, unlike other biometric traits such as face, iris or fingerprints. It can also be acquired from a distance, without any cooperation from the person being observed. Such advantages lead to gait recognition attracting significant interest of the research community [1].

1.1 State-of-the-art

Traditionally, gait recognition in a surveillance environment, i.e. under the observation of a single 2D camera [2], is performed using appearance based methods such as gait energy image (GEI), gait entropy image (GEnI) or motion energy image (MEI) [3]. These methods rely on spatiotemporal information obtained from the input images to perform recognition – see Fig. 1. Most of these methods acquire gait features from the person's body silhouettes. However, work presented in [4], suggests that gait features can also be acquired from the shadow cast by a walking person.

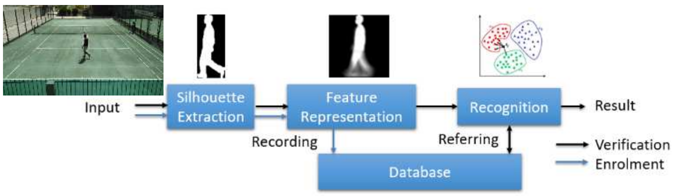

Figure 1: Appearance based gait recognition system.

Several methods that perform gait recognition using shadow silhouettes are reported in the literature, relying on features such as: spherical harmonic coefficients [5], gait contour [6], shadow gait energy image [7], or affine moment invariant coefficients [8]. Among them, methods such as [7] and [8] perform well under surveillance environments being robust to view and appearance changes. The robustness to view change in [7] is achieved by transforming the shadow silhouettes into a canonical view, where the transformation is obtained from low-rank optimization of a gait texture image consisting of shadow silhouettes. Robustness to appearance changes in [8] is achieved by assigning different weights to the altered parts of the shadow GEI.

1.2 Motivation

Among the methods presented in the state-of-the-art, it is expected that the shadow cast by a person is always sharp and appears similar to the person's body silhouette. However, this is not always true. In nature, depending on the direction of the rays emanating from the light source, one of the two different types of shadows can be cast. When the light rays travel in the same, well-defined direction, i.e. when the light source is a collimated source of light, the shadow cast by the person is sharp and displays features similar to those that can be acquired from the person's body silhouette – see Fig.2 (a). However, if the light rays have many different directions, multiple overlapping shadow contributions result in a diffused shadow. Such shadow does not possess any distinguishing characteristics of a person – see Fig.2 (b). Also, shadow segmentation methods such as [5] and [7] rely on the feet position of the person to separate the shadow from the person. Since the diffused shadow surrounds the feet of the person– see Fig.2 (b), detection of the feet position becomes impossible. Thus, identifying the type of shadows can help improve performance of the gait recognition systems by allowing them to employ a different shadow segmentation method such as the mixture of gaussians (MOG) [9] in the diffused case.

Figure 2: Shadow cast by the person: under a collimated source of light (a) and under a diffused source of light (b).

This paper presents a novel method to identify the type of shadow cast by a person. The method uses the intensity ratio between the foreground and the background to generate a histogram of intensity values. Analysing the plot allows the method to identify the type of shadow cast by the person. Use of the proposed method allows the state-of-the-art gait recognition systems that rely on shadow silhouettes to perform better in surveillance environments.

2 Proposed Shadow Type Identification Method

As shown in Fig.1, given an input sequence, the silhouette extraction module relies on background subtraction methods, such as MOG [9] or robust principal component analysis (RPCA) [10] to obtain a foreground mask consisting of the walking person's body and shadow silhouettes. Along with the foreground mask – see Fig.3 (a), these methods also provide a foreground image (FGI) and a mean background image (MBGI), as illustrated in Fig.3 (b) and (c), where the mean background image is estimated from the available video sequence.

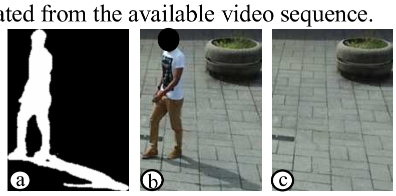

Figure 3: Outputs of background subtraction: foreground mask (a), foreground image (b) and mean background image (c).

To identify the type of shadow cast by a person only the intensity components (IC) of FGI and $MBGI$ are used to obtain an intensity ratio μ for every pixel value i, according to (1).

$$\mu_i = FGI_i^{IC}/MBGI_i^{IC} \quad (1)$$

The method then filters the intensity ratio values μ using the foreground mask to select only those intensity ratio values that either belong to the person's body or to the shadow. A histogram is then generated for the selected pixel values. The histogram plot, depending on the type of shadow cast by the person, can contain one of the two distinct shapes – see Fig.4 (a), Fig.5 (a). The difference in the plot shape is caused by the distribution of intensity ratio values in the sharp and the diffused shadow areas. The person's body area, usually having a significant contrast with the background, results in low intensity ratio values. On the other hand, a sharp shadow contains a significant contrast with its

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background and, being a darker area, also changes the background chromaticity resulting in a large number of low intensity ratio values in the histogram plot – as illustrated in Fig.4.

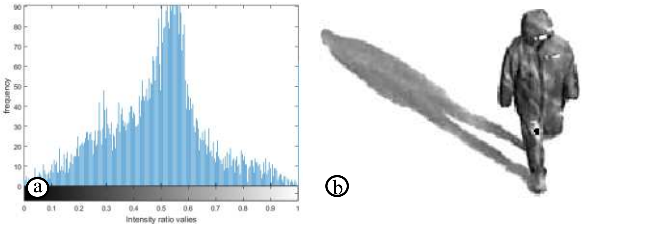

Figure 4: Sharp shadow's intensity ratio: histogram plot (a), for a sample image (b).

In the case of a diffused shadow, a significant contrast still exists between the person's body and the background. However, the diffused shadow only slightly reduces the intensity of the background, not causing significant changes to the background chromaticity. Thus, the diffused shadow generates a large number of high intensity ratio values. Therefore, the resulting histogram plot contains a significant amount of both low and high intensity ratio values, as illustrated in Fig.5.

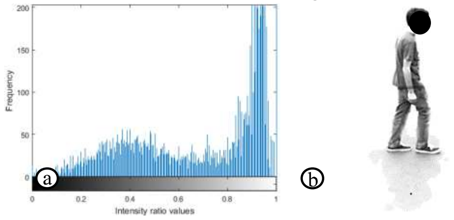

Figure 5: Diffused shadow's intensity ratio: histogram plot (a), for a sample image (b).

To automatically identify the type of shadow, the histogram is organized into 20 bins, followed by the application of a gaussian filter. The bins corresponding to peaks in the histogram are then identified, as illustrated in Fig.6. It is observed that the sharp shadows, i.e. those with low intensity ratio values, are represented by histograms with a single peak – see Fig.6 (a), while diffused shadows, i.e. containing large numbers of both low and high intensity ratio values, are represented by two clearly separated peaks – see Fig.6 (b). Therefore, depending on the number of peaks identified it is possible to have a classification of the type of shadow cast by the walking person.

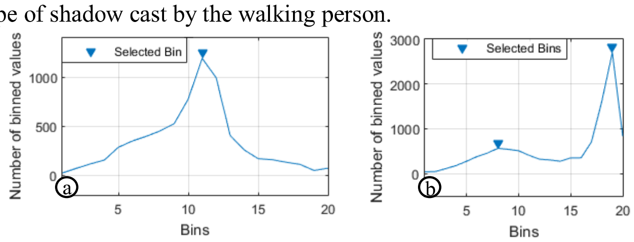

Figure 6: Bin selection for: sharp shadow (a), diffused shadow (b).

3 Results

To test the performance of the proposed method, a database is constructed consisting of six people captured across two days. On the first day, the people are recorded under a clear sky and, thus, the shadows cast by the people are sharp. On the second day, people are recorded under a cloudy sky, casting diffused shadows. The recordings are conducted at Instituto Superior Técnico, Lisbon, Portugal, on a tennis court, between 10:00 to 12:00 o'clock in the month of June. Although the recorded people are only six, around 300 frames are captured, as each person walks the full length of the tennis court– see Fig.1 (input). Thus, approximately 3600 frames are available to test the proposed method.

To test the proposed method, all the frames acquired on the first day are indexed as sharp shadow and all the frames acquired on the second day are indexed as diffused shadow. Next, the proposed method is applied to individual frames and the resulting output is matched against the index to obtain the correct identification rate.

Using the proposed method, a correct shadow type identification of 90% is achieved. During the tests, the proposed method is applied to individual frames, however, gait features are usually acquired from an integer number of complete gait cycles, each with a typical duration between 1 and 2 seconds. Thus, using a voting policy the shadow type can be identified for the entire duration of the gait cycle, further improving the proposed method's results.

In the results obtained, it is observed that some of the errors result from some sharp shadows being represented by histograms with two peaks. However, in most of these error cases, the distance between the two peaks is extremely small, allowing easy improvement in the results.

Another source of error happens when the person's attire blends in with the background, with a camouflage effect, due to the lack of contrast, resulting in high intensity ratio values in the person's body region. The proposed method is unable to distinguish between the two types of shadows under such conditions.

4 Conclusion

A person can casts either a sharp or a diffused shadow depending on the light source characteristics. A sharp shadow is cast under a collimated source of light, which is characterised by the shadow's appearance being similar to a person's body silhouette. A diffused shadow is cast when the light rays from a light source travel in different directions. In this case, the shadow appears as blob around the person with no distinctive characteristics. Most state-of-the-art gait recognition systems that rely on shadows cannot operate with diffused shadows. Similarly, some state-of-the-art shadow segmentation methods cannot separate diffused shadows from the person's body. Under such conditions, identifying the type of shadow can be useful.

The paper proposes a novel method to identify the type of shadow. The method generates a histogram of ratios computed between the foreground and background intensity values. The two types of shadows are represented with two distinct plots. Sharp shadow is saturated with low intensity ratio values, while diffused shadow contains a significant amount of both low and high intensity ratio values. Thus, the shadow type can be identified by analysing these histograms.

A contrast between the person's body and the background allows the proposed method to perform extremely well. However, when the person camouflages with the background the proposed method performs poorly. To tackle, this the future work includes the use of textures and other colour channels that better distinguish the person, shadow and the background. To further test the proposed method, the database should be expanded to include more people and diverse conditions.

References

[1] Y. Makihara, D. S. Matovski, M. S. Nixon, J. N. Carter and Y. Yagi. Gait recognition: Databases, representations, and applications. *Wiley Encyclopedia of Electrical and Electronics Engineering*. 2015.

[2] T. Verlekar, P. Correia and L. Soares, View-Invariant Gait Recognition System Using a Gait Energy Image Decomposition Method. *IET Biometrics*, 6(4): 299 - 306, 2017,

[3] Z. Lv, X. Xing, K. Wang and D. Guan. Class energy image analysis for video sensor-based gait recognition: A review. *Sensors*, 15(1): 932-964, 2015.

[4] A. Stoica. Towards Recognition of Humans and their Behaviors from Space and Airborne Platforms: Extracting the Information in the Dynamics of Human Shadows. In *Proc. BLISS*, 2008.

[5] Y. Iwashita, A. Stoica, and R. Kurazume. Person Identification using Shadow Analysis. In *Proc. BMVC*, 2010.

[6] Y. Iwashita, A. Stoica, and R. Kurazume. Finding people by their shadows: Aerial surveillance using body biometrics extracted from ground video. In *Proc. EST*, 2012.

[7] T. Verlekar, P. Correia and L. Soares. Gait Recognition Using Normalized Shadows. In *Proc. EUSIPCO*, 2017.

[8] Y. Iwashita, A. Stoica, and R. Kurazume. Gait Identification Using Invisible Shadows: Robustness to Appearance Changes. In *Proc. EST*, 2014.

[9] P. KaewTraKulPong and R. Bowden. An improved adaptive background mixture model for real-time tracking with shadow detection. *Video-based surveillance systems* 1: 135-144, 2002

[10] P. Rodriguez and B. Wohlberg. Fast principal component pursuit via alternating minimization. In *Proc ICIP*, 2013.