Extraction and Description of Moving Human Body by Periodic Motion Analysis

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Abstract

We describe a new method for extraction and description of a moving human body by periodic motion analysis from image sequences. The moving human body is detected by background subtraction using an edge difference image with noise filtering. Then, histogram projection profiles of the edge difference image are used to determine the position of the human body. This method is improved by periodic motion analysis using projection profiles in a moving window. The periodicity of human gait motion is described by a gait state diagram and primitive during a gait cycle. The usefulness of proposed method is demonstrated in experiments with comparison of other methods.

1 Introduction

Recent interest in computer vision has emerged which deals with the analysis of image sequences involving humans. This interest is motivated by the various application domains [1]: visual surveillance, virtual reality, athletic performance analysis, human-machine interface, model-based coding, and biometrics. Moreover, human motion analysis has many challenging issues, because the highly flexible structure and self-occlusion of the human body mandates complicated processes for the segmentation and analysis of the motion. The motion of the human body is known as a form of non-rigid and articulated motion [2]. Most human locomotory motions can be characterized as having a periodic component [3]. Human gait motion is one of the most universal and complex of all human activities, and it can be decomposed into periodic components in gait cycle. Also, periodicity is a very strong cue in human motion perception [4], and segmentation and analysis of periodic motion has recently been investigated for tracking or recognizing humans [4, 5, 6].

In this study, we describe a new method for extraction and description of the moving human body from image sequences, by periodic gait motion analysis. A background subtraction method using an edge difference image with noise filtering is employed to detect a moving human body. The edge difference image and the noise filter aim to make the background subtraction more robust to change in illumination. The body region in the edge difference image is determined by analyzing histogram projection profiles, and its location is verified by prior knowledge. To enhance this method, the future region of the body's position is estimated by periodic motion analysis. Also, the periodicity of gait is described by the projection of body segments in a moving window. Results show that the new approach works successfully, in comparison with results from noise filtering or prediction of body position, and should therefore prove suited to the suggested application domain.

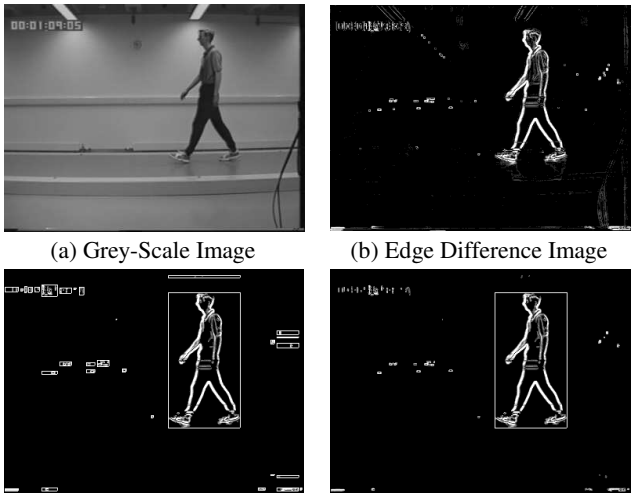
2 Extraction of Moving Human Body

To detect the human body, background subtraction [7] using an edge difference image is employed to handle any change in illumination. The background image is modeled by taking the median of an image sequence that belongs to the background [8]. The Sobel operator is then applied to each image to obtain the edge image. After that, the edge difference image between the background and the current edge image is obtained by the background subtraction. That is, let $I_{be}(x, y)$ and $I_{ce}(x, y)$ be the background and current edge images with coordinate (x, y) respectively. Then, the edge difference image $I_{ed}(x, y)$ is given by

$$I_{ed}(x, y) = I_{be}(x, y) - I_{ce}(x, y). \quad (1)$$

Figs. 1(a) and (b) show a real scene image with 384×288 grey-scale pixels acquired from an indoor scene and the edge difference image obtained by the Eqn. 1. In Figure 1(b), the edge difference image still has many small isolated areas that are caused by change illumination. These isolated areas require a more sophisticated algorithm for object detection and segmentation.

By considering these isolated areas as noise, a 3×3



(a) Grey-Scale Image (b) Edge Difference Image

(c) Block Segmentation (d) Body Detection

Figure 1: Detection of Human Body

mask operation can remove the noise areas by suppressing small areas of fixed size as

$$g(x,y) = \begin{cases} g(x,y) & \text{if } \left(\sum_{k=-1}^{1} \sum_{j=-1}^{1} f(x-j, y-k)\big|_{(j,k)\neq(x-j,y-k)} > 2 \right) \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

where $f(x, y)$ is set to 1 if it is greater than a threshold value T_n, otherwise it is set to 0. Fig. 2(a) shows the distribution for grey-scale of edge difference image, and (b) is a result of performing the mask operation of Eqn. 2. As can be seen in Figs. 1(c) and 2(b), the mask operation can remove most small isolated areas.

In addition, the histogram projection profiles are analyzed to estimate the position of a human body in the edge difference image. For block segmentation, preliminary lines are defined by a vertical projection profile. After that, to decide if multiple object lines exist in a preliminary line, a horizontal projection profile for each preliminary line is generated. Fig. 1(c) shows the several candidate body regions that are segmented by connected components included in the horizontal projection on the preliminary lines. Fig. 1(d) shows the detected human body region that is verified by prior knowledge such as size and shape. The algorithm for block segmentation and body detection adopts a clustering procedure done from the single object to the final cluster by merging small clusters. That is, the two closest regions among all possible pairs of regions are found by the distance between any two points in two regions P and Q, as evaluated by

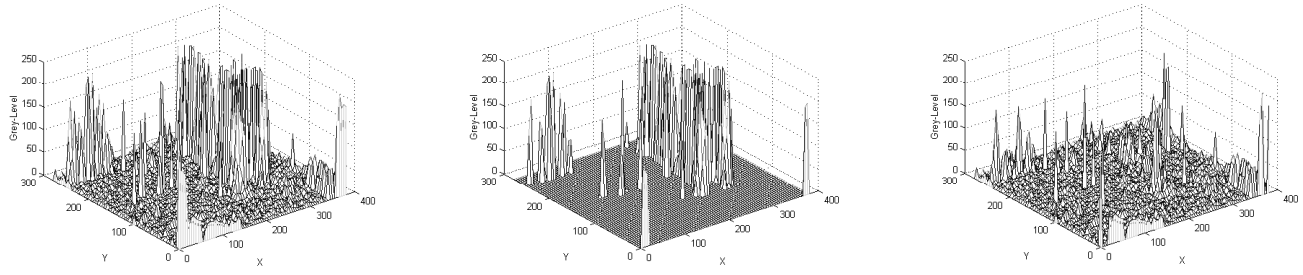
$$D_{PQ} = \min_{p\in P, q\in Q} (d_{pq}) \quad (3)$$

where p and q are elements of regions, and d_{pq} is the distance between them. The two regions are merged, if D_{PQ} less than pre-determined value T_c. This method can lead to better improvement in object segmentation in a low-quality image.

3 Human Gait by Periodic Motion Analysis

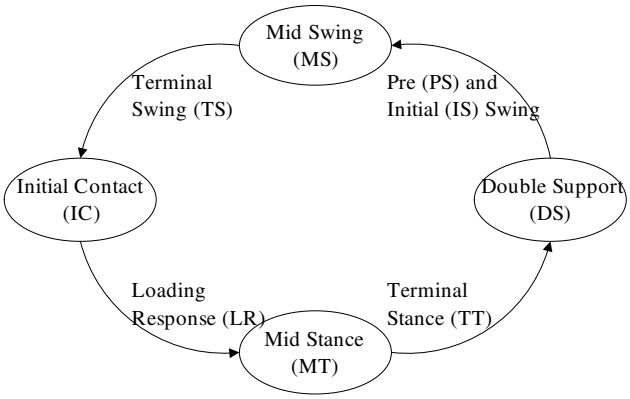
In the previous section, the human body has been detected, and a 3×3 mask operation is used to remove small isolated areas. This method is very effective and useful for object detection and segmentation through histogram projection profile. However, important information can be also lost along with the noise, especially in the low-quality images. To improve object detection and segmentation, we use information from periodicity of human gait motion. From the theoretical point of view, human gait is a form of periodic motion, especially when walking laterally; hence we can predict human movement in a gait cycle. The phases of a human gait cycle are described in Fig. 3(a). During walking, the human body functionally divides into passenger and locomotor units. The upper body is a relatively passive passenger unit that rides on a locomotor unit. Murray [9] considers human gait as "a total walking cycle" - the action of walking can be thought of as a periodic signal. Basically, each gait cycle is separated into two distinct periods: the stance and the swing phase. The stance phase is the entire period during which the foot is on the ground, and the swing phase begins as the foot is lifted from floor (toe-off). The normal distribution of the floor contact period is 60% for stance and 40% for swing [10].

To analyze the gait motion, a sufficiently sized moving window, which can include the whole human

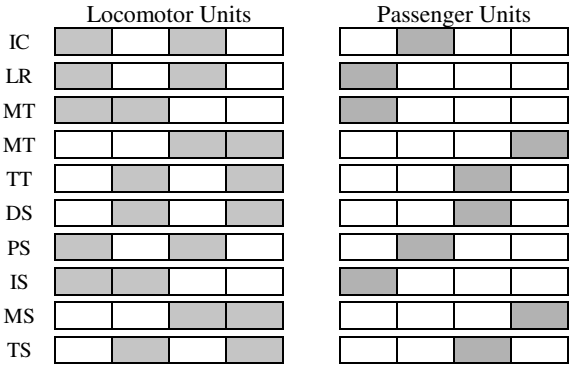


(a) Edge Difference Image (b) Noise Filtered Edge Difference Image (c) Removed Noise from (a)

Figure 2: Distribution for Grey-Scale of Edge Difference Image in Fig. 1



(a) Gait State Diagram



(b) Most Likely Positions in Gait States

Figure 3: Phases of Gait Cycle

body, is defined by data (ratio and duration) derived by analysis of free walking [11, 12]. A human gait cycle is the period between the successive heel-strikes of the same foot. During this cycle, the other foot is in contact with the floor (and does not move forwards). Let x_l and x_r be the left and right positions, respectively, of the body region in image. Then, the fixed body position x_l or x_r in an image sequence is given by

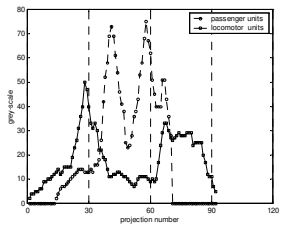
$$x_l = \begin{cases} x_{l-1} & \text{if } (gait_state = IC / LR / PS / IS) \\ x_l & \text{otherwise} \end{cases} \quad (4)$$

$$x_r = \begin{cases} x_{r-1} & \text{if } (gait_state = DS / TT / TS) \\ x_r & \text{otherwise} \end{cases} . \quad (5)$$

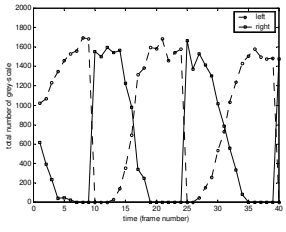
The position of the moving window is fixed by x_l or x_r, and the projection regions containing the locomotor and passenger units are extracted using guidance by known anatomical data [12]. The current state of motion (as per the gait state diagram) is determined by the most likely position of each unit (the shaded areas shown in Fig. 3(b)), in combination with the projection profile shown in Fig. 4(b). The four equally sized areas in the projection profile in Fig. 4(b) are defined by the expected positions in Fig. 3(b). By this method, the state of human gait motion in Fig. 4(a) can be considered as initial contact or pre-swing (IC or PS), therefore we can also predict the following state of gait and fixed position x_l.

An image sequence is used to detect the periodicity of gait motion. Figs. 4(c) and (d) show the time varying counts of pixel data for two locomotor units and the left and right upper torso (passenger units) respectively, in each image. Periodicity is evident in both time series, though slightly more clearly in Fig. 4(d). We can observe that the states of mid-stance and mid-swing (which are the crossing points between the left and right legs) are repeated so these measures describe a periodic motion, consistent with human gait.

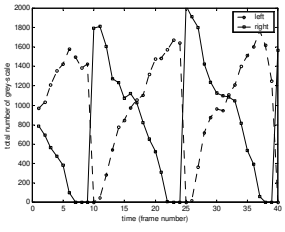
(a) Extracted Human Body



(b) Projection for Body Units



(c) Variation of Locomotor Units



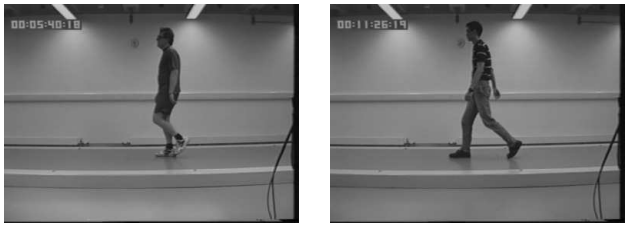
(d) Variation of Passenger Units

Figure 4: Periodicity Analysis of Human Gait Motion using Project Profiles

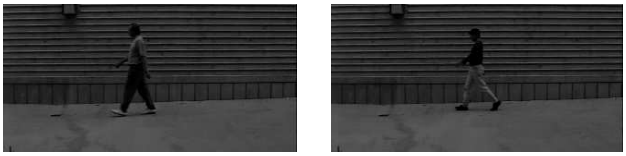
4 Results

In the experiments, 200 test images of 4 different image sequences taken indoors and outdoors are used. Fig. 5 shows examples of the test images. The size of the human body in the indoor images is approximately 100×180 pixels in 384×288 grey-scale image, and the size in the outdoor images is usually less than 50×100 pixels in 320×160 image. Extraction of the human body region is performed by three different algorithms: *i*) background subtraction by Eqn. 1; *ii*) background subtraction followed noise filtering and merging by Eqns. 2 and 3; and *iii*) the second method plus moving window by Eqns. 4 and 5.

The comparison results are summarized in Table 1. Success is decided by whether the detected region includes the whole human body or not. The first algorithm is sensitive to neighborhood noise, so it detects a bigger region than the real body in many cases. The second algorithm demonstrated better performance than the first method. However, this algorithm is sensitive to the



(a) High-Resolution Images (384×288, Indoor)



(b) Low-Resolution Images (320×160, Outdoor)

Figure 5: Examples of the Test Images

threshold value (T_n) for noise reduction in the low-resolution images, and the noise filtering also loses some body information. The outdoor images have less illumination noise than that of indoor, but have problems in horizontal projection caused by complex background.

Table 1: Experimental Results

Methods		*i*) Edge difference image	*ii*) With noise filtering	*iii*) With moving window
High-resolution images (indoor)	Test images	100	100	100
	Success rate (%)	82	99	100
Low-resolution images (outdoor)	Test images	100	100	100
	Success rate (%)	55	73	97

The third algorithm shows the best performance for detecting human body with good accuracy in indoor and outdoor images, but this algorithm is also sensitive to the threshold value. This new algorithm clearly has greater accuracy when detecting the body's position.

5 Conclusions

We have shown how a new state description, representing gait as periodic motion, can be used to improve further the extraction of an ambulatory human figure from within image sequences. These measures are derived by a new approach that employs projection profiles, aiming to reduce the effects of noise. To detect the human body, background subtraction using edge difference image with noise filtering is used to reduce the effects of change in illumination. Moreover, this method is improved by periodic motion analysis using projection profiles in a moving window and the primitive for human gait. Periodicity of human gait motion is also observed by analyzing the projection profile of locomotor and passenger units. As such, this new approach appears to track or recognize the human motion. In future we seek to clarify the technique in terms of application capability as well as analyzing a large database of subjects.

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