Active Shape Model-Based Gait Recognition Using Infrared Images

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Abstract

We present a gait recognition system using infra-red (IR) images. Since an IR camera is not affected by the intensity of illumination, it is able to provide constant recognition performance regardless of the amount of illumination. Model-based object tracking algorithms enable robust tracking with partial occlusions or dynamic illumination. However, this algorithm often fails in tracking objects if strong edge exists near the object. Replacement of the input image by an IR image guarantees robust object region extraction because background edges do not affect the IR image. In conclusion, the proposed gait recognition algorithm improves accuracy in object extraction by using IR images and the improvements finally increase the recognition rate of gaits.

Keywords: *Active shape model, Gait recognition, Object tracking*

1. Introduction

Recently, human recognition techniques have attracted increasing attention in intelligent surveillance applications. For recognition systems using Physiological feature-based human recognition systems use individual, unique characteristics, such as fingerprints, iris, and face. Because of the unique nature, the physiological feature-based system provides very high recognition rate up to 99%. In spite of the high recognition rate, the physiological features are not easily acquired due to the reluctance of participants. Alternatively, human behavioral features gains increasing attractions in applications for in conscious recognition of humans using gaits. [1][2][3]

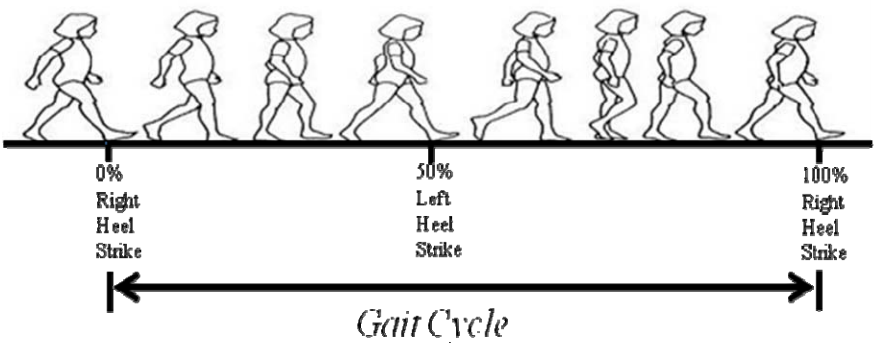


Figure 1. A single walking cycle of a person.

In gait recognition, we process video images to derive numerical information that reflects the identity of the moving object. Cutting and Kozlowski [4] showed that this recognition enables identification of friends. After Cutting and Kozlowski's experiment, there have been various experiments to show that humans can recognize gender, direction, and weight of a moving object. Classification of selected gait recognition algorithms is shown in Table 1 [5]. Shape-based techniques are mainly based on the silhouette of the object, while model-based techniques use various parameters for meaningful features.

Table 1. Classification of various gait recognition approaches.

	Shape-based analysis		**Model-based analysis**	
1977 to 2000	Moving Shape		Model	
	spatiotemporal pattern [6]; Principal Components Analysis(PCA) [7]	shape of motion [17]; PCA + Canonical Analysis [18]	single oscillator [31]	
Since 2001	**Without motion**	**With motion**		
	unwrapped silhouette [8]; silhouette similarity [9]; relational statistics [10]; self similarity [11]; key frame analysis [12]; frieze patterns [13]; area [14]; symmetry [15]; key poses [16]	eigenspace sequences [19]; average silhouette [20]; moments [21]; ellipsoidal fits [22]; kinematic features [23]; gait style and content [24]	stride parameters [25]; human parameters [26]; joint trajectories [27]; hidden Markov model [28][29];	articulated model [32]; dual oscillator [33]; linked feature trajectories [34]
		video oscillations [30]		

Accurate infrared target tracking is critical in many military weapons systems where common knowledge indicates that improving infrared target detection and tracking has the potential to simultaneously minimize unwanted collateral damage and maximize the probability of successful target elimination [35].

Gait recognition is a technology to identify a human based on the difference in a cycle of steps representing a behavioral feature. Most existing gait recognition techniques use CCD camera images, which are sensitive to illumination changes. The proposed gait recognition method is able to extract the object region using infrared (IR) images. Even under row-level illumination or complex background, an IR image contains the easily extracting object region.

This paper is organized as follows. In section 2, we present the ASM algorithm for infrared images. Extraction method of the gait data is presented in section 3. Section 4 presents the experimental results and section 5 concludes the paper.

2. Active Shape Model for Object Extraction in Infrared Images

The proposed algorithm deals with several basic computer vision problems such as matching and comparing temporal signatures object and background, modeling human motion and dynamics, and shape recovery from partial occlusions. It is well known that the extraction of object area is very difficult with complex background or partial occlusions.

In this section we present a novel gait recognition system by deploying the ASM framework using the infrared video. The advantage of the proposed system is the robust recognition with complicated background, poor illumination, and occlusions.

We briefly revisit the ASM theory divided by including three steps: (a) shape variation modeling, (b) model fitting, and (c) local structure modeling.

2.1. Shape Variation Modeling

Given a frame of input video, initial landmark points should be assigned on the contour of the object either manually or automatically. Good landmark points should be at or close to the desired boundary of each object. A particular shape X is represented by a set of n landmark points which approximate its outline as

$$X = [x_1, x_2, \cdots, x_n, y_1, y_2, \cdots, y_n]^T, \tag{1}$$

Different sets of such landmark points make a training set. A shape in the training set is normalized in scale, and aligned with respect to a common frame. Although each aligned shape is in the $2n$-dimensional space, we can model the shape with a reduced number of modes using the principal component analysis (PCA) analysis. The main modes of the template model, X, are then described by the eigenvectors φ of the covariance matrix c, with the largest eigen-values.

2.2. Model Fitting

We can find the best shape and pose parameters to match a shape in the model coordinate frame, x, to a new shape in the image coordinate frame, y, by minimizing the following error function

$$E = (y - Mx)^T W^T (y - Mx), \tag{2}$$

where M represents the geometric transformation of scaling (s), translation (t), and rotation (θ). For instance if we apply the transformation to a single point, denoted by $[p, q]^T$, we have

$$M\begin{bmatrix} p \\ q \end{bmatrix} = s\begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}\begin{bmatrix} p \\ q \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix}, \tag{3}$$

After a set of pose parameters, $\{\theta, t, s\}$, is obtained, the projection of y on to the model coordinate frame is given as

$$x_p = M^{-1} y. \tag{4}$$

Finally, the parameters are updated as

$$b = \phi^T (x_p - \bar{x}). \tag{5}$$

2.3. Local Structure Modeling

In order to interpret a given shape in the input image based on ASM, we must find a set of parameters that best match the model to the input shape. If we assume that the shape model represents boundaries and strong edges of the object, a profile across each landmark point has an edge like local structure. The nearest profile can be obtained by minimizing the following Mahalanobis distance between the sample and mean of the model as

$$f(g_{i,m}) = (g_{i,m} - \bar{g})^T S_g^T (g_{i,m} - \bar{g}), \tag{6}$$

where $g_{i,m}$ represents the shifted version of g_i by m samples along the normal direction of the corresponding boundary.

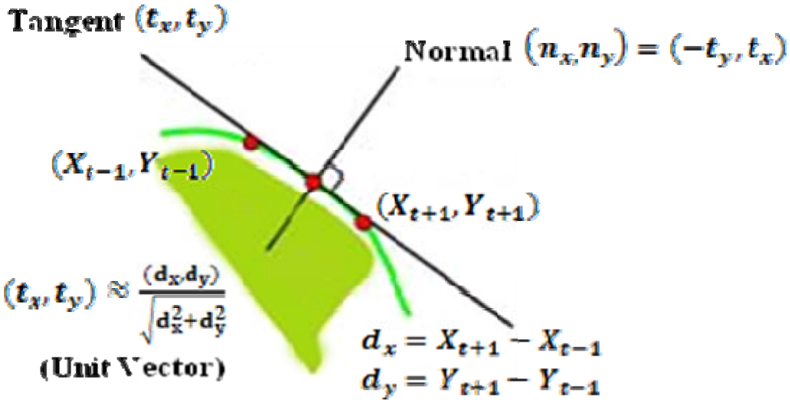


Figure 2. Model fitting along the profile normal to boundary edge.

In practice, we look along profiles normal to the model boundary through each model point as shown in Fig.2. If we want the model boundary to correspond to an edge, we can simply locate the strongest edge along the profile.

3. Extraction of Gait Data

In this section we present an object region extraction method based on the analysis of the object in section 2. For the analysis of human gait it is very important to extract the gait period. Most gait period extracting methods measure object features in the image on the basis of temporally proceeding frames. The proposed gait recognition method analyzes the shape of an object in the form of a four-dimensional (4D) vector as shown in Fig.3 in order to acquisition 4D data.

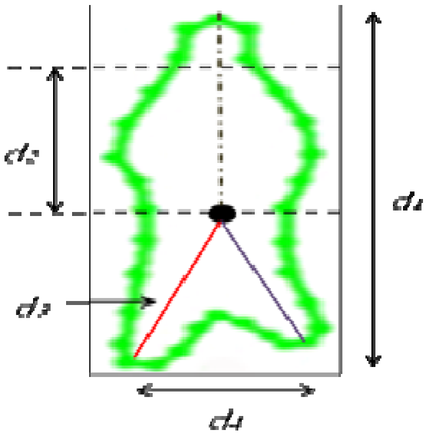


Figure 3. A 4D vector with four gait parameters: $W = [d_1, d_2, d_3, d_4]^T$

The 4D vector consists of the height of the object shape (d1), the length of the upper torso (d2), from the pelvis to the foot length (d3), and the distance between the left and right foot (d4). We can detect the eigen gait by using the extracted 4D gait vectors. For normally obtained gait data, d4 data shows the periodic property and has the unique feature. Extracted 4D gait vectors are store in the database for future comparison with an arbitrary input data.

These distances are only measured at the maximal separation point of the feet during the double support phase of the gait period, and concatenated to from a four-dimensional walk vector $\mathbf{W} = [d_1, d_2, d_3, d_4]^T$ for each object. Measurements are taken only at these points because the body parts are not self-occluding, and the maximum value of the following frame determines the gait period.

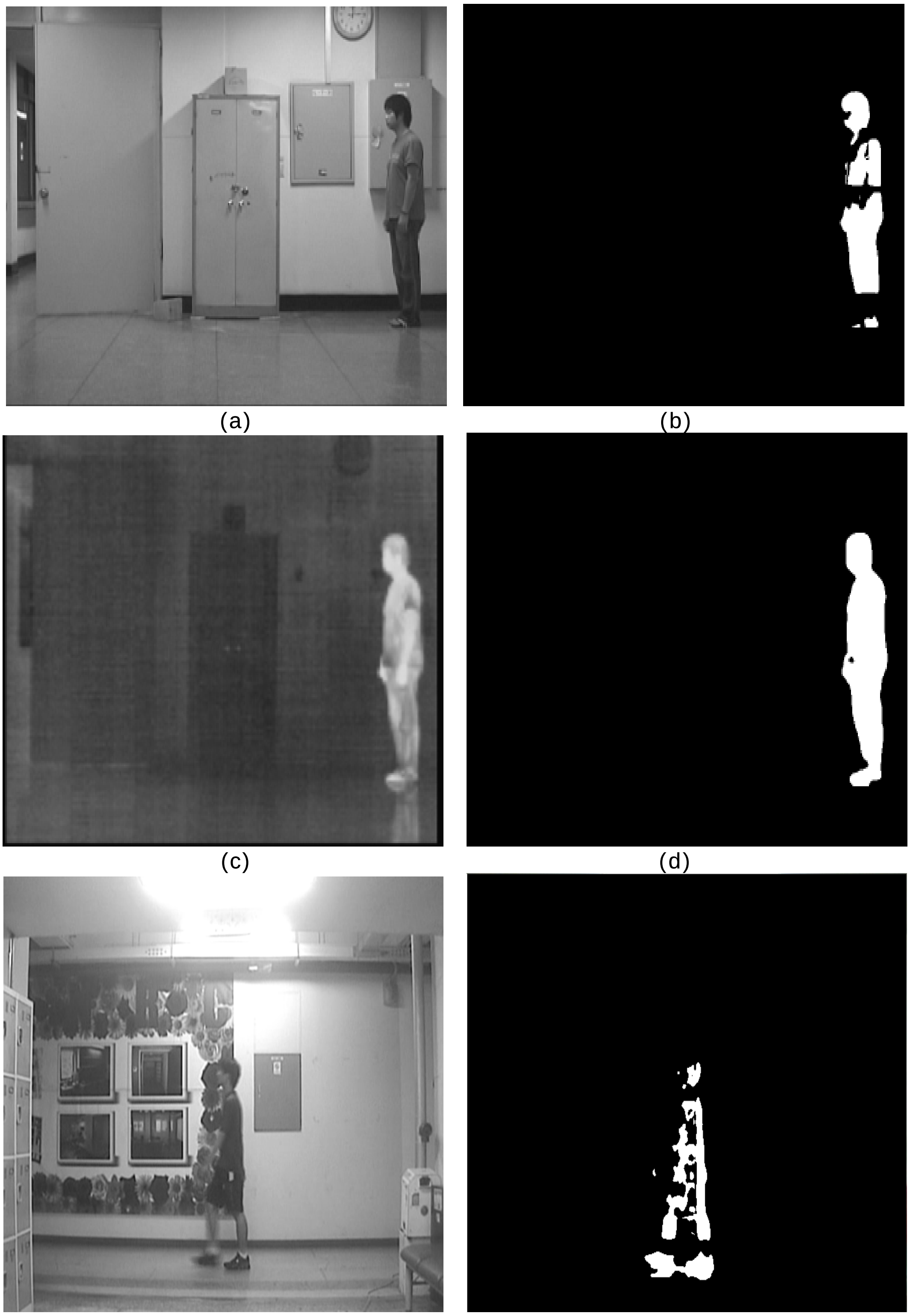
In the recognition process the cross-correlation of the 4D gait vectors extracted from the input image and from the stored database as,

$$c(n) = \sum d_i^{DB}(m) \cdot d_i^{input}(n+m), \text{ for } i = 1, 2, 3, 4. \quad (7)$$

The stored gait data with the maximum correlation is selected as the best matching candidate. Where d_i^{DB} represents the element of the i-th gait vector in the stored database, d_i^{input} the element of the i-th vector extracted from the input image, and $c(n)$ the cross-correlation shifted by n frames.

4. Experiment Results

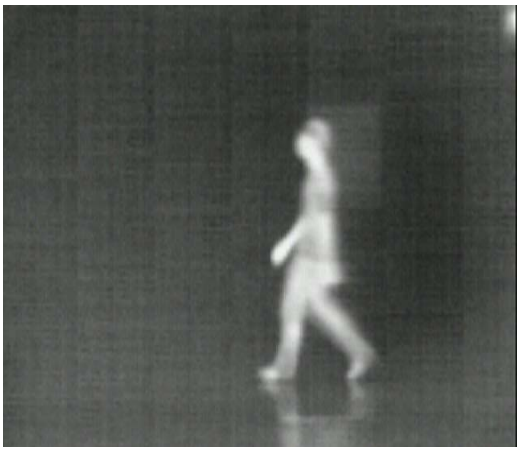
We first compare object extraction performance using a CCD and an IR images. While the object was extracted by subtraction from background in the CCD image, the object in the IR image was extracted by using an experimentally chosen threshold as shown in Fig. 4.



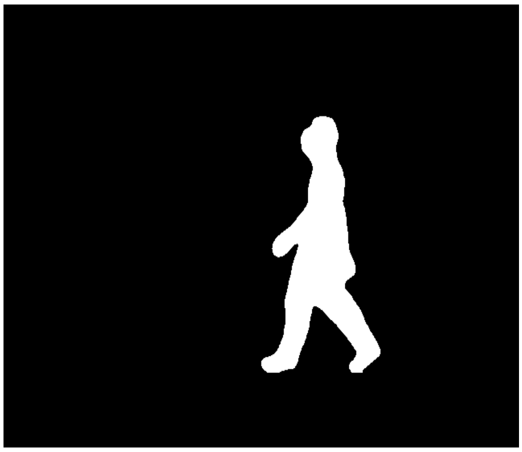
(a) (b)

(c) (d)

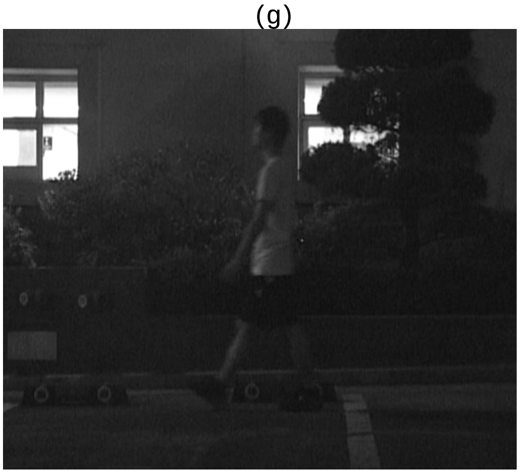
(e) (f)



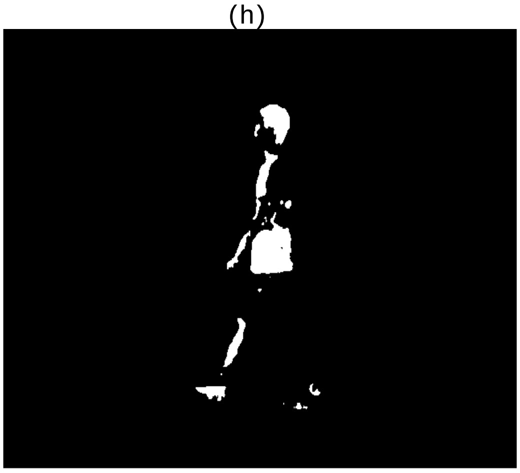
(g)



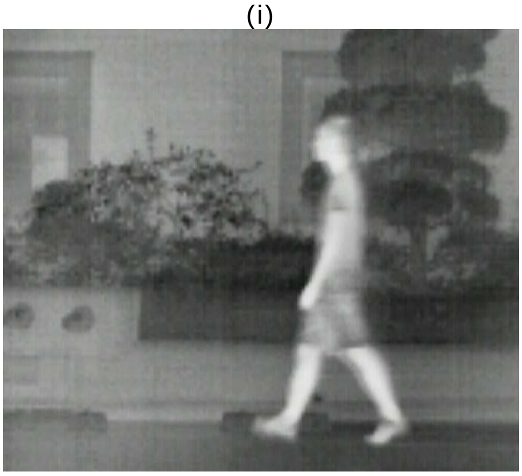
(h)



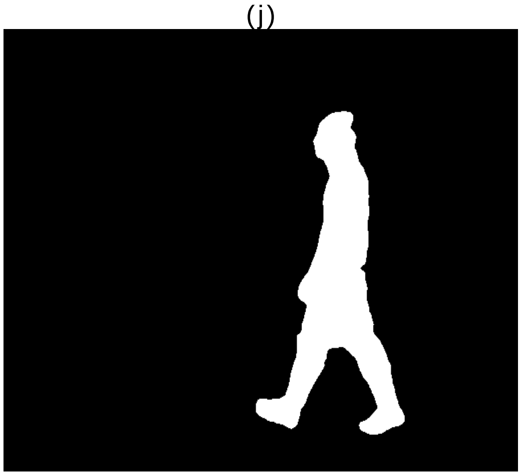
(i)



(j)



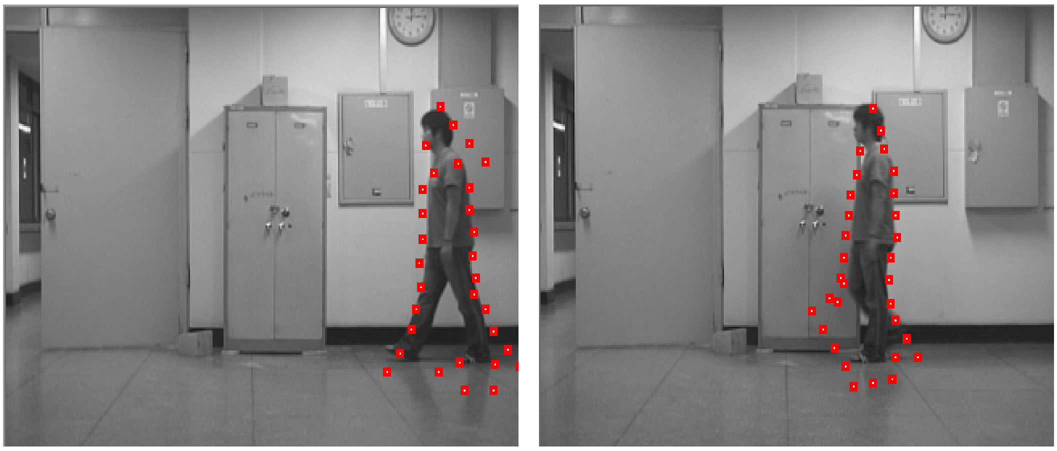
(k)



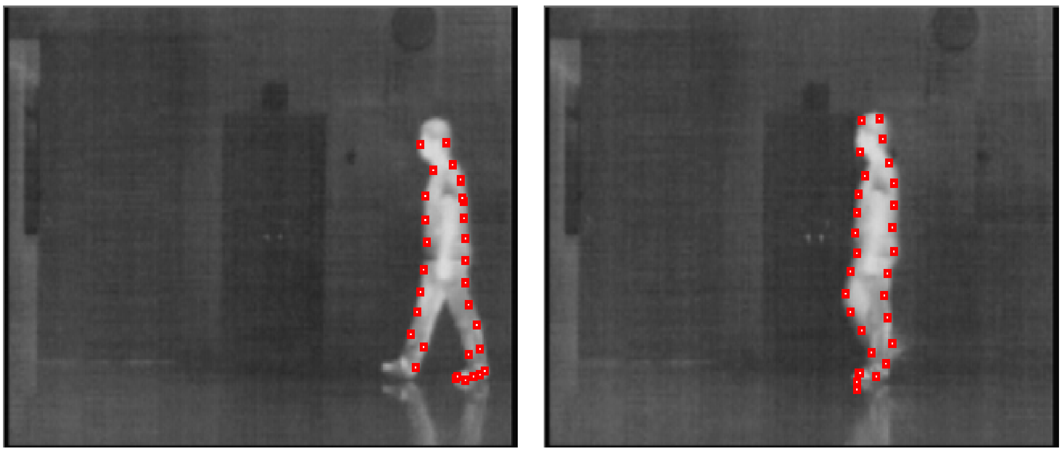
(l)

Figure 4. (a) Input CCD image, (b) extracted object in the CCD image, (c), (g), (k) input IR image, (d), (h), (l) extracted object in the IR image, (e) complex background, (f) extracted object in the complex background, (i) the row-level illumination.

Fig. 5 show results of the ASM in the CCD and IR images. For the CCD image, a number of mismatches are observed near the contour of the object. However the IR image provides the significantly improved shape of the object.



(a) 22th frame (b) 55th frame



(c) 22th frame (d) 55th frame

Figure 5. The ASM results in the CCD and IR images.

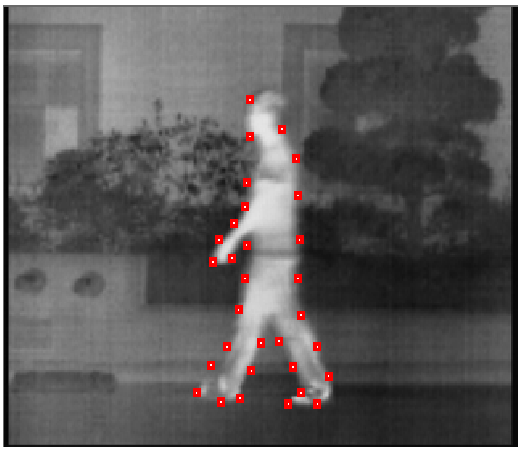
Table 2 summarizes the value of shape-accuracy of CCD and IR images using the ASM, respectively. The matching-ratio is achieved by using manually-assigned ground truth data.

Table 2. Comparison of matching-ratio results.

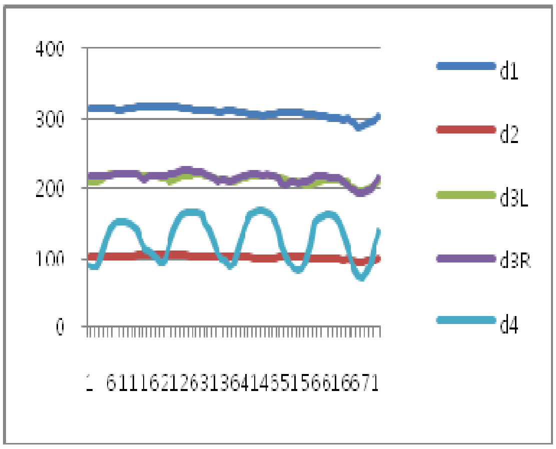
Camera	object	Suitability	Disagreement	Matching ratio(%)
CCD	Object 1	21	11	62.6
	Object 2	18	14	56.3
IR	Object 1	30	3	93.8
	Object 2	29	3	90.6

(a) CCD image

(b) IR image



(c) The ASM result in the IR image



(d) Extracted 4D gait date

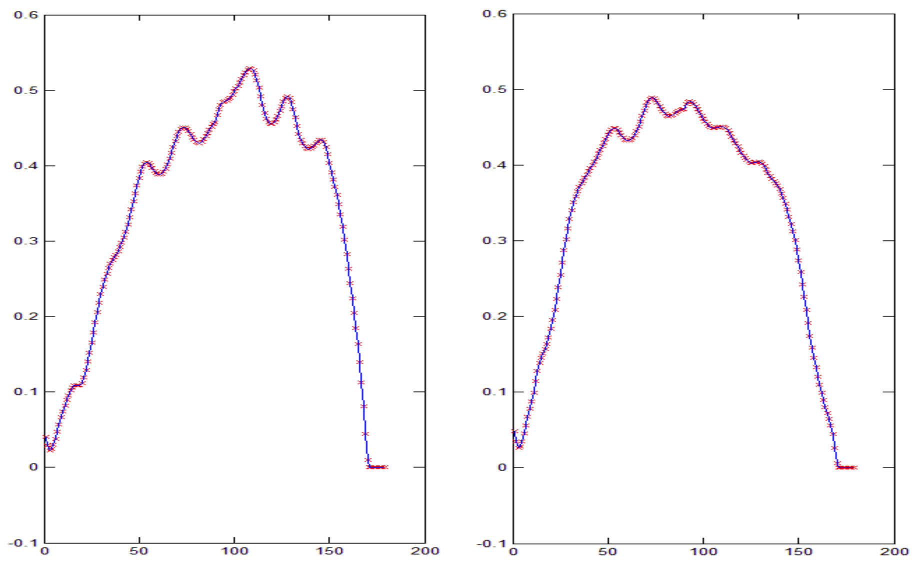
Figure 6. The ASM results in the row-level illumination images

Fig.6 shows the ASM results and gait data in the row-level illumination images acquired by both CCD and IR cameras. The region of object and gait data are clearly extracted in the IR image. On the other hand the appearance of the object is not clear in the CCD image.

Fig.7 (a) shows the measured gait data using cross-correlation when the same object walks in the different areas, and Fig.7 (b) shows the obtained gait data using cross-correlation when the different object walks in the same areas.

5. Conclusion

In this paper we obtain the gait data using the ASM in the IR image. Experiment results show that the proposed system can robustly extract the object region at the row-level illumination or with partial occlusion. For the future development of the gait recognition system, we need to consider conditions, to acquire input images to accurately simulate more practical situation.



(a) (b)

Figure 7. The results of cross-correlations: (a) The same person walking in different locations, and (b) two different people walking in the same location.

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