Robust Gait Identification with Belongings From Back View

Toshiaki Hirooka
Graduate School of Informatics and Engineering
The University of Electro-Communications
Tokyo, Japan
h1730092@edu.cc.uec.ac.jp

Hiroki Takahashi
Graduate School of Informatics and Engineering
The University of Electro-Communications
Tokyo, Japan
rocky@inf.uec.ac.jp

***Abstract*— Gait is one of the biological information which indicates how to walk. Gait is able to acquire from a distance and any views. It is, however, difficult to identify a person with belongings. The purpose of this paper is, therefore, to propose an effective identification method when the subject has a bag. First, GEI(Gait Energy Image) is generated with head position adjustment. Then, gradient of GEI for head, both arms and leg regions are obtained. Finally, features are obtained from each region except for the hand region with a bag and the bag itself in the leg region. The proposed method obtains 95.0% identification ratio for back view gait with belongings.**

Keywords*— *Biometrics Identification, Gait, Back view, Belongings

I. Introduction

Since the September 11th terrorist attacks in 2001, biometric authentication has been paid attention to as an advanced personal identification method. These are currently introduced as aims for the criminal investigation and access control at important infrastructures such as airports, main roads and so on.

Gait is one of the biometric information that indicates how to walk. It can be obtained from any angles without approval of subjects. Especially, it is hard for the back view to identify the subject by using other biometric information. It is also reported that the accuracy of the gait identification decreases when a subject walks with belongings.

This paper, therefore, proposes a robust gait identification method for changes in silhouette when a subject has a bag.

II. Related Works

J. Han et al.[1] propose GEI(Gait Energy Image) which is the average image of a silhouette sequence as shown in Fig.1. Gait silhouettes from side view in USF HumanID Database[2] are identified. Low quality silhouette images generated by randomly adding noise are examined to verify its tolerance to image quality. The identification accuracy achieves 90% for gait without belongings by using GEI. It is, however, hard to correctly identify a subject with belongings. The accuracy is just up to 64%.

978-1-5386-2615-3/18/$31.00 ©2018 IEEE

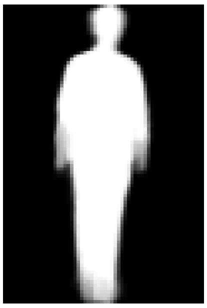
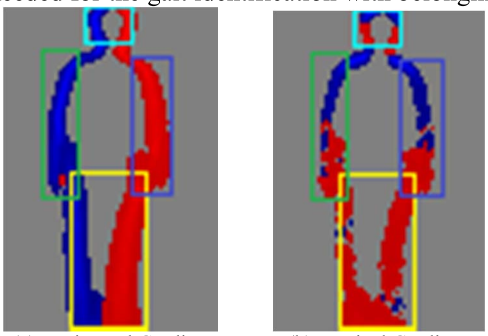


Fig.1 Example of GEI

G. Momose et al.[3] propose an identification method based on velocity distribution of body parts' movement from GEI. First, GEI is generated with head position adjustment. Then, horizontal and vertical gradients of GEI for head, both arms and leg regions are obtained as local gait features illustrated in Fig.2. Identification is examined to silhouette images obtained from back view included in CASIA Gait Database[4]. The accuracy becomes 98.1% for gait without belongings. Appropriate belonging region segmentation from silhouette is, however, needed for the gait identification with belongings.



(a) Horizontal Gradient (b) Vertical Gradient

Fig.2 Example of split back gait feature

III. Gait Identification by Local Gradient Distribution of GEI

The proposed method is based on the gait identification algorithm for local gradient distribution of GEI[3]. The method is roughly classified into three steps as depicted in Fig.3. First step is silhouette extraction from images. In the second step, local gait features are obtained from the silhouette. Finally, an individual is identified by using PCA(Principal Component

Analysis) and k-NN(k-Nearest Neighbor) in the local gait feature space. This paper employs the same algorithms as the first and third steps proposed in [3].

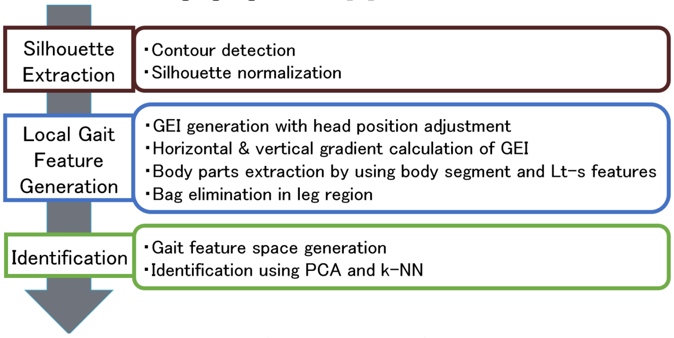


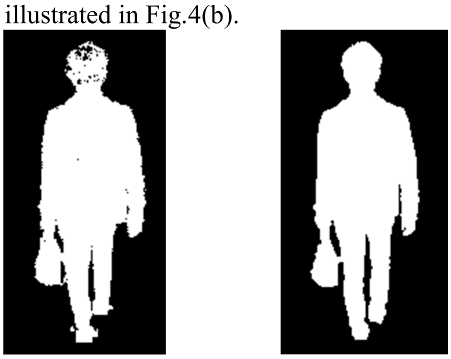
Fig.3 Process overview

A. *Gait data generation with belongings*

Gait data including belongings with the left hand are provided in CASIA Gait Database[4]. Since details are not clear for the belongings in the database, alternative gait data with a bag are generated by using Microsoft® Kinect™ v2.

Kinect™ can easily extract a human silhouette in its fundamental functionality. Unfortunately, the extraction range is confined within 0.5*m* to 4.5*m* from it. Gait sequences are, therefore, captured by Kinect™ on a carriage moving with a subject so that distance between Kinect™ and the subject becomes constant.

Fig.4(a) presents a human silhouette image extracted by using Kinect™. The silhouette is not extracted appropriately because a large number of holes occur in the head region. GraphCut[5] is, therefore, employed for extracting correct human region. GraphCut is applied for a RGB image, where the silhouette shown in Fig.4(a) is used as initial labels. The final silhouette is illustrated in Fig.4(b).



(a) A silhouette by Kinect™ (b) A final silhouette by GraphCut
Fig.4 Gait data with belongings

B. *GEI generation with head position adjustment*

G. Momose et al.[3] assumes that the center of silhouette corresponds with the centroid of a human. GEI is generated to superpose the centers of all silhouettes. The center of a silhouette with belongings departs, however, from the centroid of a human as shown in Fig.5(a). A head region locates at the upper part of a silhouette according to the body segment[6]. In this paper, the horizontal centers of head regions as illustrated in Fig.5(b) are, therefore, superposed to generate GEI. Fig.6 presents a GEI with head position adjustment.

(a) The center of silhouettes (b) Head position adjustment
Fig.5 The centers of silhouettes with belongings

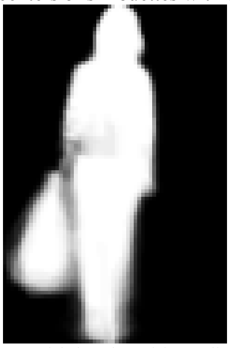


Fig.6 GEI with head position adjustment

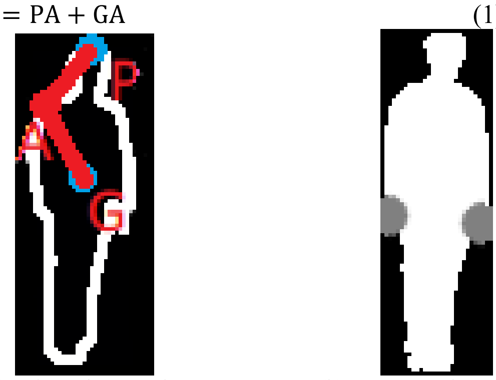
C. *Body Parts extraction by using body segment and Lt-s features*

The horizontal right and the vertical downward direction represent x and y axis, respectively. W and H denote the width and the height of GEI. Let $G(x, y)$ indicate a pixel value of GEI at (x, y).

Head and leg regions are extracted according to the body segment. Head region is within $0.5W - 0.087H \leq x \leq 0.5W + 0.087H$ and $0 \leq y \leq 0.13H$. Leg region is within $0.5W - 0.1245H \leq x \leq 0.5W + 0.1245H$ and $0.52H \leq y \leq H$.

Left arm and right arm regions by using the body segment are, however, not appropriate because Arm swings are varied from person to person. The arms regions are extracted by using Lt-s features[7]. The centroid of body represents G. P denotes the intersection point of principal axis of inertia and contours. Lt-s feature is obtained for each contour point shown in Fig.7(a). The obtained feature is illustrated in equation (1).

$$\mathrm{Lt} - \mathrm{s} = \mathrm{PA} + \mathrm{GA} \qquad (1)$$



(a) Points of P, A and G (b) Representative points
Fig.7 Lt-s features

4 points which is the maximum and minimum of the Lt-s features in x and y are obtained. These are labeled to a point of

head, right arm, left arm, or leg arm region. Other contour points are labeled to the region which is the nearest obtained point. The point which has the maximum value of the Lt-s in right arm and left arm labels is a representative point of each region illustrated in Fig.7(b).

The rectangle regions are comprised of all representative points in each labels. If the point is not within $0.1H \leq y \leq 0.7H$, the point is excluded, empirically. All regions are obtained as a rectangular area illustrated in Fig.8.

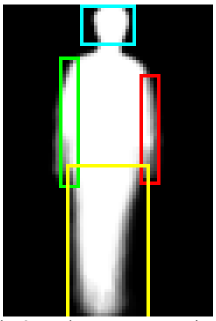


Fig.8 Body parts extraction

D. *Left arm region removal*

Since arm with belongings has no original gait features, the head, right arm and leg regions are used for identification. The left arm region is excluded.

E. *Elimination of belongings in leg region*

Belongings overlaps with the leg region even if the left arm region is excluded as shown in Fig.9. It is necessary to detect and eliminate belongings from the leg region.

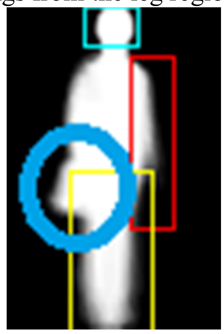
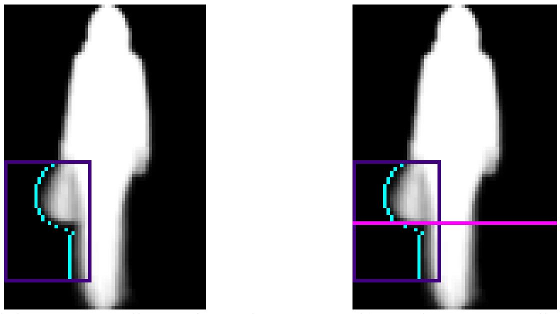


Fig.9 Example of belongings in the leg region

This paper assumes that belongings are on the left hand. Belongings can be extracted on the presupposition that the belongings region is restricted within a certain range. At first, the maximum y-coordinate of the belongings region is obtained. Search ranges are restricted within $0 \leq x \leq 0.429W$ and $0.52H \leq y \leq 0.9H$ in this paper. Minimum x-coordinate $\mathrm{Min_x(y)}$, which represents non-zero pixel for each y, is obtained as illustrated in Fig.10(a). The formula is indicated by the equation(1). Differences between $\mathrm{Min_x(y-1)}$ and $\mathrm{Min_x(y)}$ are obtained. $\mathrm{Max_y}$ represented by the equation(2) gives y-coordinate which maximizes the difference. Fig.10(b) shows the obtained $\mathrm{Max_y}$.

$$\mathrm{Min_x(y)} = argmin_x(G(x,y) \neq 0) \quad (1)$$

$$\mathrm{Max_y} = argmax_y\big(\mathrm{Min_x(y)} - Min_x(\mathrm{y}-1)\big) \quad (2)$$



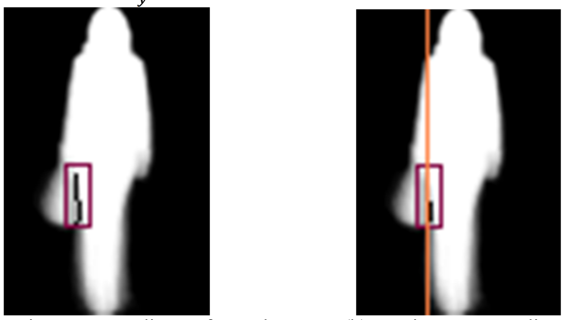
(a) Minimum x-coordinates for each y (b) Maximum y-coordinate

Fig.10 Maximum y-coordinate of a belongings region

Next, the maximum x-coordinate of the belongings region is obtained. Search ranges are restricted within $0.5W - 0.1245H \leq x \leq 0.429W$ and $0.52H \leq y \leq \mathrm{Max_y}$. The pixel values on the boundary between the belongings and the body regions becomes smaller than these adjacent pixel values in the GEI because the belongings do not always overlap with the body. Maximum x-coordinate $\mathrm{Max_x(y)}$, which gives local minimum pixel value for each y, is obtained as depicted in Fig.11(a). The formula is given by the equation(3). Maximum x- coordinate of the belongings region $\mathrm{Max_x}$ is defined by the equation(4). The obtained $\mathrm{Max_x}$ is illustrated in Fig.11(b).

$$\mathrm{Max_x(y)} = arglocalmin_x(G(x,y) \neq 0) \quad (3)$$

$$\mathrm{Max_x} = \frac{1}{Max_y - 0.52H}\sum \mathrm{Max_x(y)} \quad (4)$$



(a) Maximum x-coordinates for each y (b) Maximum x-coordinate

Fig.11 Maximum x-coordinate of a belongings region

The overlap of the leg and the belongings region drawn in Fig.12 is extracted as the belongings in the leg region.

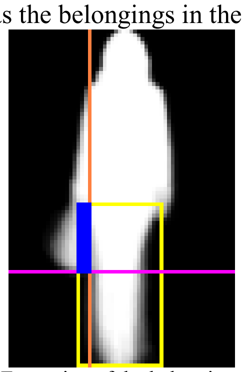
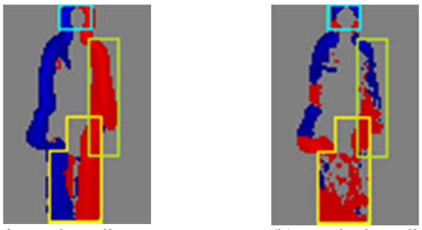


Fig.12 Extraction of the belongings region

A bounding box of the union of all obtained belongings regions for all GEIs is set to a common belongings region.

F. *Local gait feature generation*

Vertical and horizontal gradients in the head, right arm and leg regions excluding belongings are extracted as local gait features shown in Fig.13.



(a) Horizontal gradients (b) Vertical gradients

Fig.13 Local gait features

IV. Experimental Results

A. Gait identification without belongings

Gaits without belongings of 105 subjects with six trials for each included in CASIA Gait Database[4] are identified by 3-fold cross validation. Four out of six trials are employed for training data and two trials are employed for test data. At first, influence of the head region adjustment is investigated for gait without belongings. The identification results are presented in Table 1.

Table 1. Gait identification without belongings

	# of correct identification	Identification ratio (%)
G. Momose et al.[3]	618/630	98.1
Proposed method	618/630	98.1

Next, influence of arm region removal is examined. The identification results are shown in Table.2.

Table 2. Gait identification without belongings by parts of features

	# of correct identification	Identification ratio (%)
All four local regions	618/630	98.1
Three regions excluded the left arm	610/630	96.8
Three regions excluded the right arm	612/630	97.1

B. Gait identification with belongings

Gaits with belongings of 40 subjects included in CASIA Gait Database[4] are identified in the same way described in the previous subsection. Table 3 gives the identification results.

Table.3 Identification with belongings

	# of correct identification	Identification ratio (%)
J. Han et al.[1]	38/80	47.5
G. Momose et al.[3]	45/80	56.25
Proposed method	76/80	95.0

Gaits with belongings obtained in Subsection III.A are identified. Four trials without belongings of 115 subjects, which consist of 105 subjects from CASIA Gait Database[4] and 10 subjects obtained in Subsection III.A, are employed for training data. Two trials with a bag, which includes 0*Kg* and 5*Kg* weight, obtained in Subsection III.A are employed for test data. The identification results are presented in Table.4.

Table 4. Result of identification against change of weight

Weight	# of correct identification	Identification ratio(%)
0*Kg*	22/24	91.7
5*Kg*	19/24	79.2

V. Conclusions and Futre Works

This paper proposes a gait identification from the back view that is robust algorithm to appearance changes in silhouette caused by belongings. The proposed method gives identification ratio of 95% of gaits with belongings. It also shows superiority to the previous methods[1],[3]. Moreover, identification ratio of 91.7% is archived when subjects bring a lightweight bag. In this case, silhouettes are only varied. When subjects bring a packed bag, identification ratio of 79.2% is obtained. In this case, both of silhouettes and walking postures are varied. It indicates robustness to the appearance changes in silhouette and gait itself.

Although the current method does not include a belongings detection process, if belongings detection should perfectly perform, it would give identification ratio of 98.1% when subjects do not possess belongings. If belongings detection should not perform well, identification ratio would archive 96.8% in the same case.

In future tasks, the belongings region extraction should be improved. We are planning to extract belongings from color images directly in advance to generate GEI.

Refeernces

[1] J. Han and B. Bhanu, "Individual Recognition Using Gait Energy Image", IEEE Trans. PAMI, vol.28, no.2, pp.316-322, 2006

[2] S. Sarkar, P.J. Phillips, Z. Liu, I.R. Vega, P. Grother and K.W. Bowyer, "The Humanid Gait Challenge Problem: Data Sets, Performance, and Analysis", IEEE Trans. PAMI, vol.27, no.2, pp.162-177, 2005

[3] G. Momose and H. Takahashi, "Individual Identification by Using Rear Gait Feature", ITE technical report, 38(7), pp.335-340, 2014(in Japanese)

[4] S. Yu, D. Tan, T. Tan: "A Framework for Evaluating the Effect of View Angle, Clothing and Carrying Condition on Gait Recognition", IEEE ICPR 2006, vol.4, pp.441-444, 2006

[5] Y. Boykov, O. Veksler, and R. Zabih, "Fast approximate energy minimization via graph cuts", IEEE Trans PAMI, vol.23, no.11, pp.1222-1239, 2001

[6] R. Drillis, R. Contini and M. Bluestein, "Body Segment Parameters: A Survey of Measurement Technics," Office of Vocational Rehabilitation, Artificial Limbs, vol.8, no.1, pp.44-66, 1964

[7] K. Takahashi, R. Sakaguchi, and J. Ootani, "Remarks on a Real-Time, Non-contact, Non-wear, 3D Human Body Posture Estimation Method," ICICE(D-II), Vol.J83-D-II, No.5, pp.1305-1314, 2000(in Japanese)