Performance Evaluation of GEI for Impairment Detection

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1. Introduction

People who have some impairment, such as a person whose leg is immobilized in a plastic cast, an elder person who cannot bend his/her knees, and a cataract patient, show different walking styles comparing with normal walking. We can usually distinguish such the difference easily just by observing their ways of walking. If it can be realized by a computer, it would be great useful in fields of disease diagnosis, elderly care, and human-oriented commercial service. In a commercial facility, for example, such a system would be helpful for staffs to find and assist a person with impairment immediately.

There are several studies that investigate the difference between normal and abnormal walking. Considering the sensors used in the experiments, these research can be mainly divided into two categories: invasive sensor based methods [1], [2], [3], and non-invasive sensor based methods [4], [5]. The former ones use motion capture systems or the wireless inertial sensor system. They are, however, not available to the real applications; it is impossible to make people wear such special devices. We thus choose the latter one; we use a camera to capture walking.

As a feature representation of gait, we use Gait Energy Image (GEI) [6] originally proposed for the person authentication task. A supervised learning approach is applied to classify the normal and impaired walkings. In addition, we give intuitive consideration about which part of a human's body is most different between the normal and abnormal walkings.

The main contribution of this paper is to evaluate performance of GEI, which is originally for the person authentication, for discriminating the normal and impaired walkings. The results are reliable since we use an adequately large dataset consisting of more than a hundred subjects.

2. Methods

2.1 Experimental Data Acquisition

We need to collect as many subjects as possible for reliable investigation. It is, however, difficult to find so many

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Fig. 1 Examples of walking with knee supporters and goggle.

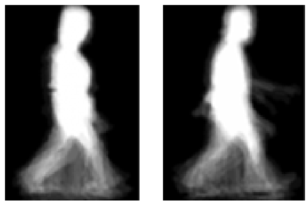


Fig. 2 GEI images.

subjects who really have impairments. In our study, therefore, we used knee supporters that restrict bending knees to simulate leg impairment, and a goggle glass which narrows their fields of view to act as visual impairment, as shown in Fig. 1. Each subject walked on a straight path, wearing the supporters on both legs, wearing the goggle, or wearing neither of them. A camera captured the subject from his/her side. The subject number of walking with goggles is 142; the number of walking with both leg supporters is 186 and the number of subject who wears nothing is 325.

2.2 Gait Feature

From the captured color image sequences, we extracted binary silhouette images of the subjects by the background subtraction method. We call this image sequence Gait Silhouette Volume (GSV). From the GSV, we then calculated Gait Energy Image (GEI) [6] which is the average silhouettes over one walking cycle sequence. Fig. 2 shows two examples of GEI features. The intensity of the gray image means the frequency of the human body appearance at the corresponding pixel, which can describe the silhouette shape and walking shape of a walking subject.

2.3 Classification Method

Before distinguishing the walking styles using GEI, firstly

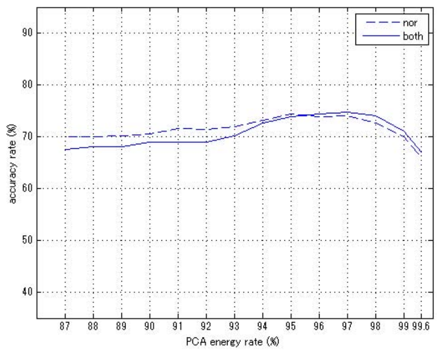
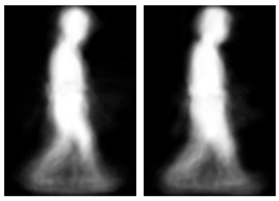


Fig. 3 Graph of relation between PCA dimension and classification accuracy.

normal vs. leg impairment	
normal	74.6%±2.2%
leg impairment	75.4%±2.3%



leg impairment vs. visual impairment	
leg impairment	80.0%±2.2%
visual impairment	78.9%±2.3%

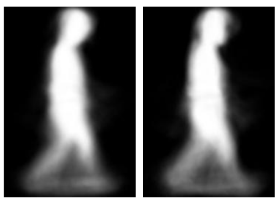


Fig. 4 Two-category classification and the re-projection images.

the Principal Component Analysis (PCA) is applied to the feature vector to reduce redundancy. Usually the original features are compressed into the dimensions which preserve a certain rate, 90% for example, of the total energy. From our experiments, however, we found that these dimension number cannot guarantee the best classification results. Fig. 3 is a graph which describes the relation between PCA dimension and classification accuracy. We thus choose the number of dimensions which gives the highest classification accuracy.

To separate the normal and impaired walkings, Linear Discriminant Analysis (LDA), which finds a axis which maximizes between-class variation and minimizes within-class variations simultaneously, is applied. We then perform the leave-one-out cross validation. Moreover, we re-projection the obtained axis to a pattern. This re-projection is used to show the mainly distinguishing region between the two categories.

3. Experimental Results and Discussion

Fig. 4 shows experimental results. As the subject number of normal walking is larger than the other impaired walking styles, we randomly selected the same number of subjects of the normal walking as that of the impaired walking to balance then on the the training phase. We performed the

nor vs.leg impairment vs. visual impairment		
normal	leg impairment	visual impairment
66.0%±4.0%	63.2%±2.5%	72.5%±2.6%

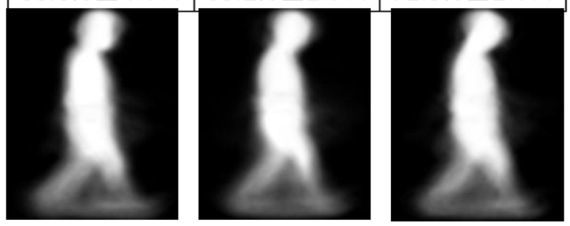


Fig. 5 Three-category classification results and he re-projection images.

selection 30 times. The percentage shown in the tables on the right side is the average accuracy of those trials. On the left side, we show the re-projection of most discriminate vector calculated by LDA to illustrate the difference between the normal and impaired walkings. Moreover, Fig. 5 shows results when we discriminate three categories; the normal, leg-impaired, and visually-inpaired walkings.

From the results, we confirmed that GEI is quite effective for distinguishing between the normal and impaired walkings. We found that it is a little more difficult to discriminate between normal and leg-impaired ones. The reason is considered by observing the re-projection images. The people with visual impairment tend to bend their heads more to the front to take care of their steps. The leg-impaired ones are a little more subtle. We can, however, still find consistent difference in their leg region; the leg-impaired ones have a smaller angle then the normal walking, and tend to bend their body a little comparing with the normal walking.

Future work contains increasing the number of subjects to achieve more reliable evaluation.

Acknowledgments

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