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Short Paper

Gait recognition based on joint distribution of motion angles

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ABSTRACT

Gait as a biometric trait has the ability to be recognized in remote monitoring. In this article, a method based on joint distribution of motion angles is proposed for gait recognition. The new feature of the motion angles of lower limbs is defined and extracted from either 2D video database or 3D motion capture database, and the corresponding angles of right leg and left leg are joined together to work out the joint distribution spectrums. Based on the joint distribution of these angles, we build a feature histogram individually. In the stage of distance measurement, three types of distance vector are defined and utilized to measure the similarity between the histograms, and then a classifier is built to implement the classification. Experiments has been carried out both on CASIA Gait Database and CMU motion capture database, which show that our method can achieve a good recognition performance.

1. Introduction

Biometrics refers to the identification of humans by their characteristics or traits [1]. The characteristics include but not limited to face, fingerprint, iris, gait and DNA. However, the current recognition methods, such as face, fingerprint or iris based, require a cooperative subject or physical contact. So it is nearly impossible to identify people at a distance by using these methods. However, gait as the way people walk does not have these constraints. In the past decades, many studies have proven that gait has the potential to become a powerful biometric for surveillance and access control, since it has advantages such as noninvasive, hard to conceal and capable of being acquired at a distance [2]. In fact, besides being well-suited to identify people at a distance, gait also has the potential to be applied in the medical field. For example, recognizing changes in walking patterns early can help to identify conditions such as Parkinson's disease and multiple sclerosis in their earliest stages [3]. Although gait has some limitations, e.g., it may not be as unique as fingerprint or iris, and may be affected by one's clothing, shoes or physical condition, the inherent gait characteristic of an individual still makes it irreplaceable and useful in visual surveillance.

Nowadays, video is not the only way to collect the gait any more. According to the ways of data collection, gait recognition methods can be divided into three categories: Video Sensor (VS) based, Floor Sensor (FS) based and Wearable Sensor (WS) based [4]. VS-based method collects gait data by video cameras. Without physical contact, VS-based method is the most noninvasive way and can get the most natural way of one's walking. Moreover, video cameras are widely used in our daily life, so it is quite easy to get the gait data in a variety of occasions. However, they require image processing to process images captured from cameras in order to get the gait information. The most widely used field of VS-based method is remote monitoring. FS-based method is also called footprint method, which puts the sensors on the floor and record

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the information of one's footprint such as length and location. WS-based method needs the subject to wear sensors and records their motion data. Different from VS-based method, WS-based method can get the motion data directly and the data are more suitable for gait analysis. WS-based method is popularly used in gait analysis mainly for medical purpose. However, it is not a good choice for remote monitoring as the noninvasive is the key feature. The gait data can be represented in 2D or 3D. 2D data are presented by the sequence of images widely used in early days, while gait recognition based on 3D data became a new trend nowadays. The 3D data are mainly acquired and calculated by motion capture technology.

In this article, we propose a new method based on joint distribution of motion angles for gait recognition, which can work on 2D video database or 3D motion capture database. First, we extract the motion angles of lower limbs from the original data to obtain their joint distribution spectrums. Then, we build the feature histogram and calculate the distance between the histograms. Finally, we build a classifier to implement on the distance vector to recognize the gaits.

As for the experiments data in this article, we use the CASIA Gait Database [5] from the Institute of Automation, Chinese Academy of Sciences as the 2D data source, and the CMU motion capture database in ASF/AMC format [6] as 3D data. In the stage of motion angle extraction, we only use the motion angles of lower limbs, because this part of body is a major impact factor on the classification, and compared with other model-based methods using the posture data of the whole body (see below), limiting the data to lower limbs can greatly save computation time. After the motion angles are extracted, we take the result as a time-free model instead of considering them as a time sequence model. The spatial distribution of them, however, is what we concerned. In other words, we only care about the postures of the subject when he is walking. Experimental results are compared with other similar work which demonstrates our method can reach a higher accuracy with a fixed view frame angle.

The reminder of the article is organized as follows: Section 2 is the related work. Section 3 shows the feature definition and extraction. Section 4 describes the classification. Section 5 presents the experiments and the results. Section 6 concludes the article.

2. Related work

Gait recognition method has been well studied and many methods have been proposed which can be classified into model-free and model-based approaches [7]. In the model-free approaches, moment of shape is one of the most commonly used features. In addition, silhouette and statistical features are widely used in a lot of work. In this approach, the correspondence between successive frames is established based upon the prediction or estimation of features related to position, velocity, shape, texture and color. Alternatively, they assume some implicit notion of what is being observed [8]. In the model-based approaches, the prior information or a known model is needed to fit human gait. Though the model-based method is more complex, it has some advantages such as immunity to noise [9]. The model-based approaches assume a priori model to match the data extracted from video, and features correspondence is automatically achieved. These two kinds of methods both follow the general framework of features extraction, features correspondence and high-level processing. The essential difference between these two approaches is whether a model is used to fit the bounding contours of the walker.

The model-free approaches had a rapid development in the early days. Wang et al. [10] put forward a recognition method based on shape analysis, and presented the static pose changes of these silhouettes over time. Then Procrustes shape analysis was implemented to obtain gait signature. Collins et al. [11] presented a key frame identification technology which is view point dependent on the basis of the outline template of the human body. Cuntoor et al. [12] studied the dynamic characteristics of the front view and side view, took the motion features such as the motion of arms, legs and body shaking features into consideration for gait information identification, and improved the recognition rate to some extent. In [13,14], based on the appearance and view point, Kale et al. presented the binarization contour as the feature using the Dynamic Time Warping (DTW) to deal with the speed changes in the process of walking, and strengthen the fault tolerance of original data. In addition, Kale et al. [9] use the width of the outer contour of the binarized silhouette as the image feature and built a HMM model to distinguish the dynamic features of the gait. Hu et al. [15] also built a HMM model for gait recognition where they took the local binary pattern descriptor as the motion feature. Davis and Bobick [16] proposed the temporal template first which is for appearance-based action representation. They used the motion energy images (MEIs) and motion history images (MHIs) to represent motion sequences. In recent years, the depth information of the silhouette is also used as the motion feature for gait recognition. Chattopadhyay et al. [17] put forward a novel feature known as Pose Depth Volume which is based on the depth frame.

As a model-based approach, Cunado et al. [18,19] mapped the leg movement of human body to a pendulum model. It contains a pendulum motion model and a structural model. The lower limb was modeled as two interconnected pendulums. Yam et al. [20] calibrated the rotation of thigh and curves manually, and extracted the transformation of the angles as the feature. Yilmaz and Shah [21] proposed a model-based method to extract the joints of lower limbs from lateral walking sequences. Bouchrika and Nixon [22] studied the effects of covariates, such as footwear, load carriage, clothing and walking speed for gait recognition. The accuracy of the model-based method is not as high as the one based on the contour, but the fault tolerance is strengthened.

In recent years, with the development of 3D technology, more and more research focus on the motion features analysis on 3D data. The 3D data are more accurate than the traditional video data and include more information of human gait. Ariyanto and Nixon [8] used the Soton Multi-biometrics Tunnel to acquire 3D data, and an articulated cylinder model was built to analyze the features such as