Title	Robust gait recognition using adaptive random depth subspace from depth information
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Citation	
Issue Date	2014-09
Type	Thesis or Dissertation
Text version	author
URL	http://hdl.handle.net/10119/12268
Rights	
Description	Supervisor:Atsuo Yoshitaka, School of information science, Master

Robust gait recognition using adaptive random depth subspace from depth information

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August 7, 2014

Keywords: Robust gait recognition, depth information, Microsoft Kinect, Subspace, Random.

Identifying individual by biometrics is a challenging task and has been studied extensively in recent year. Human walking is a complex locomotion which is more advantageous than other traditional biometric modalities such as, face, fingerprint and iris, since gait features can neither be imitated nor hidden easily. Furthermore, walking data acquisition doesn't require a close distance capture and high quality sensors. In addition, the complete unobtrusiveness without cooperation or contact to the subject also makes gait recognition attractive in many applications.

Researchers proposed a number of approaches for identifying individual by gait. However, there are a number of covariates that affect the performance of gait recognition of individual when appearance-based approaches are applied such as view point and clothing type. The traditional gait recognition using binary images performed best when a side view point image is applied. However, depth information provided by depth sensors, such as Kinect, contains the information of physical distance from the sensor to a human body part at each pixel while walking, and it shows good performance in frontal gait recognition. Meanwhile, related works which focus on recognition of individual using depth data proposed whole-based methods and perform worse when a subject changes his/her clothing type or baggage carrying conditions. Since these methods treat each body part equally ignoring the influence of various clothing types and walking postures, and classify the subjects by global descriptor which involves interferences due to various walking conditions.

In this study, the author concentrates on exploring the applicability of depth information for robust gait recognition of individuals from frontal viewpoint. The contributions of this thesis is that proposing a part-based approach named adaptive random depth subspace (ARDS) to represent the walking pattern by local descriptors (subspaces). The proposed method is more advantageous than the related works in the following point: 1) The local descriptor is able to avoid the negative effect of covariates (changing clothes and carrying objects) and improves the accuracy in gait recognition of individual. 2) Only normal walking condition (wearing T-shirt, regular pair of pants and natural swinging arms) is assumed in gallery set for references, which is realistic in real-world applications. 3) The proposed method is capable of selecting gait features from each body part adaptively without assuming the walking condition in each test gait sequence.

Each subject's gait sequence is defined as a series of static images which are extracted frame-by-frame from the depth gait video in one full gait cycle. In preprocessing stage, subject's silhouette is segmented by removing the background. The gait features through the walking process can be extracted completely in a full gait cycle. Then, each subject's silhouette is normalized into the same size by scale variation and aligned by the position of the subject's neck.

In the stage of depth gait representation, the author proposed a gait representation technique, which is motived by 'Depth Gradient Oriented Histogram Energy Image (DGHEI)', as a gait template for selecting adaptive random depth subspace. Firstly, the depth gait images are averaged over a gait sequence. Then, Computation of the gradient values at each preprocessed gait image is the next step. Then, the gradient orientations are quantized into 9 orientations. The oriented gradient histogram of a square image chunk (8×8 pixels) is stored in a vector (which is called 'cell'). All cells are reconstructed to a matrix accounting the original location of the square image chunks and normalized in a region (which is called 'block'). Then, the calculated cell-based matrix is considered as the depth gait representation instead of the depth gait images.

In the stage of adaptive random depth subspace framework, the human body region is segmented into 4 body parts. Then, without assuming specific clothes type and baggage carrying condition for each input test sequence, the author selects cells from each body part randomly and combine the selected cells to new gait features, which is called 'subspaces'. In particular, the location of each selected cell in test sequence is consistent with all sequences in gallery set for retaining the spatial information efficiently. Meanwhile, all of cells which contain the same value of zero are discarded from the candidate cells, because most of these cells correspond to the background and do not contribute discrimination for individual recognition. For deciding the number of subspaces selected from each body part, the author proposes a method which is named 'adaptive proportion assignment'. The proportion of subspace number in each body part of an input test gait sequence is decided adaptively and automatically based on the pixel number distribution under different walking condition. Here, the author designs the fuzzy membership function to calculate the probability of being unaffected due to changing walking condition in each body part.

Finally, in the individual classification stage, a subspace extracted from a test sequence is matched with all subspaces extracted from the sequences in a gallery set. The final decision of classification is taken by majority voting.

Experiments are conducted on a new depth gait database captured with Microsoft Kinect assuming several walking conditions. Experimental results showed the effectiveness compared with other methods using depth information.