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HUMAN GAIT RECOGNITION UNDER VARIOUS VIEWING ANGLES

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Abstract It is well recognized that gait is an important biometric feature to identify a person at a distance, e.g., in video surveillance application. However, in reality, change of viewing angle causes significant challenge for gait recognition. A novel approach using regression-based view transformation modeln (VTM) is proposed to address this challenge. Gait features from across views can be normalized into a common view using learned VTM(s). In principle, a VTM is used to transform gait feature from one viewing angle (source) into another viewing angle (target). It consists of multiple regression processes to explore correlated walking motions, which are encoded in gait features, between source and target views. In the learning processes, sparse regression based on the elastic net is adopted as the regression function, which is free from the problem of over fitting and results in more stable regression models for VTM construction. Based on widely adopted gait database, experimental results show that the proposed method significantly improves upon existing VTMbased methods and outperforms most other baseline methods reported in the literature. Several practical scenarios of applying the proposed method for gait recognition under various views are also discussed in this paper.

Keywords: Biometrics fusion, face recognition, gait recognition, video-based recognition

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INTRODUCTION

GAIT IS A USEFUL biometric feature for identifying a walking person at a distance. In the real world, human gait can be affected by various factors including variations of viewing angle, walking speed, type of cloth, type of shoe, and carrying an object [1], [2].GAIT is a useful biometric feature capable of recognizing human at a distance by inspecting their walking manners. It has been used mainly in security surveillance applications such as authentication of individuals and detection of suspicious behaviors/persons. Such systems play a decisive role in monitoring high security areas including banks, airports, military bases, and railway stations. Gait is practically useful in these domains because it can be captured remotely and surreptitiously without any physical contact or proximal sensing. However, in practice, view change has been regarded as one of the most challenging problems for gait recognition [1]. View change will significantly alter available visual features for matching. Thus, gaits from different views must be normalized before their similarity is measured. Currently, there are three major categories of approaches to address such problem. They are briefly summarized as below.

A. Related Works

Methods in the first category [2]–[4] are to construct 3-D gait information through multiple calibrated cameras. Then, 2-D gait information from any required view is reconstructed from the3-D gait information. However, the methods in this category are only suitable for a fully controlled and cooperative multi camera environment such as a biometric tunnel [5] which is costly and complicated.

B. Introduction to the Proposed Method

This paper proposes a new method in the second category, which has several advantages as below. Compared with the first category, the second category uses a simpler non cooperative camera system. Compared with the third category, the second category does not rely on supervised training for view-normalization process. Thus, the normalization is not limited to the trained views but is applicable for any view. Compared with the state-of-the-art [7] of the same category (i.e., the second category),

the proposed method performs view normalization on the gait silhouettes instead of the key joints (i.e., lower limbs' poses). This will have two main benefits: 1) it does not require tracking of the key joints which can be unstable on marker less motion estimation; 2) it contains more reliable gait information after the view-normalization process, which can lead to better recognition performance.

C. Rationale of the Proposed Method

The proposed GTI works well with TILT for the view-normalization. This is because GTI of any individual always has a lowest rank when it is constructed from the canonical view. Thus, TILT is to seek the domain transformation which can

project GTI obtained from a certain view onto the canonical view by minimizing the rank of the texture image despite gross

sparse errors. In this paper, the canonical view is more close to side view which has been regarded as the best view for recognizing gaits [18], [19].

D. Summary of Contributions and Advantages

In summary, the main contribution of this paper is to propose a new framework of view-invariant gait recognition. It includes the following aspects.

• Seeking gait information (i.e., GTI) that can be normalized across different views.

• Proposing a novel view-normalization process through domain transformation by TILT on GTI.

• Normalizing gait silhouettes based on corresponding domain transformation.

• Computing a novel view-invariant gait feature through an improved scheme of PSA on view-normalized gait silhouettes.

II. FRAMEWORK OF THE PROPOSED SOLUTION

Fig. 1 shows the framework of the proposed solution for view-invariant gait recognition (the detailed frameworks of its key processes will be shown in Figs. 2 and 7).

In these figures,

Fig. 1.Proposed framework of view invariant gait recognition. Rectangles represent inputs/outputs, while ellipses represent processing steps. Given a probe gait and a gallery gait recorded from different views, they are individually processed through the processes of view normalization and feature extraction.

Then, their similarity is measured under a common canonical view. A gait silhouette can be extracted from each frame in a video gait sequence using the method in [1]. However, some extracted silhouettes are incomplete. In this paper, mathematical morphological operations [23] are used for holes remedy and noise elimination. Since gait is a periodic action, it is analyzed within complete walking cycle(s). The method in [12] is adopted to estimate gait period of each gait sequence. In the view normalization process, Gait Texture Image (GTI)is extracted from a sequence of gait silhouettes within a complete walking cycle. It will be the input of low-rank texture optimization. Transform Invariant Low-rank Textures (TILT) [17]is applied on GTI to seek a convex optimization that enables

robust recovery of low-rank textures based on domain transformation despite gross sparse errors. In this way, TILT will transform GTI from any view into a common canonical view (i.e., approximate side view) where the low-rank textures are optimized.

Another key component of TILT is sparse error matrix. It is used to eliminate errors/noises caused by corruption, occlusion, or shadow on gait image which may interfere the process of low-rank optimization. The recovered domain transformation is then reapplied to transform each corresponding gait silhouette into the canonical view. The sequence of view normalized gait silhouettes will be further used in gait recognition procedure. As mentioned in the introduction above, to address the challenge remaining from the view-normalization, a scheme of Procrustes Shape Analysis (PSA) [20] is applied for gait feature extraction and similarity measurement. The preprocesses of shape boundary extraction and shape resampling are applied on each view-normalized gait silhouette to generate the resampled shape boundary which will be described using Pair wise Shape Configuration(PSC) [6]. PSC describes a shape using a first-order derivative (i.e., tangent) of the shape boundary.

CONCLUSION

This paper proposes an innovative video-based fusion system, which aims at recognizing noncooperating individuals at a distance in a single-camera scenario. Information from two biometrics sources, side face, and gait, is combined using different fusion methods. Side face includes the entire side views of eye, nose, and mouth, possessing both shape information and intensity information. Therefore, it has a more discriminating power for recognition than face profile. To overcome the problem of a limited resolution of a side face at a distance in video, we use ESFI, a higher resolution image constructed from multiple video frames instead of OSFI directly obtained from a single video frame, as the face template for an individual. ESFI serves as a better face template than OSFI since it generates more discriminating face features. Synthetic match scores are generated for fusion based on the characteristics of face and gait. The experimental results show that the integration of information from side face and gait is effective for individual recognition in video. The performance improvement is always archived when appropriate fusion rules, such as the Max rule and the Sum rule, are used to integrate information from ES FIand GEI. Consequently, our fusion system is relatively robust compared with the system using only one biometrics in the same scenario.

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