Chapter 9
Gait Feature Fusion using Factorial HMM

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ABSTRACT

Multisource information fusion technology offers a promising solution to the development of a superior classification system. For gait recognition problem, information fusion is necessary to be employed under at least three circumstances: 1) multiple gait feature fusion, 2) multiple view gait sequence fusion, and 3) gait and other biometrics fusion. Feature concatenation is the most popular methodology to integrate multiple features. However, because of the high dimensional gait data size and small available number of training samples, feature concatenation typically leads to the well-known curse of dimensionality and the small sample size problems. In this chapter, we explore the factorial hidden Markov model (FHMM), an extended hidden Markov model (HMM) with a multiple layer structure, as a feature fusion framework for gait recognition. FHMM provides an alternative to combining several gait features without concatenating them into a single augmented feature, thus, to some extent, overcomes the curse of dimensionality and small sample size problem for gait recognition. Three gait features, the frieze feature, wavelet feature, and boundary signature, are adopted in the numerical experiments conducted on CMU MoBo database and CASIA gait database A. Besides the cumulative matching score (CMS) curves, McNemar's test is employed to check on the statistical significance of the performance difference between the recognition algorithms. Experimental results demonstrate that the proposed FHMM feature fusion scheme outperforms the feature concatenation method.

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INTRODUCTION

Biometrics refer to the automatic identification of a person by measuring and analyzing its physiological or behavioral characteristics, such as fingerprints, eye retinas and irises, facial patterns and gait patterns. Gait recognition is the process of identifying an individual by its walking style. In comparison with other biometric characteristics, gait patterns have the advantages of unobtrusive, difficult to conceal, non-invasive and effective at a distance. Therefore, gait recognition has attracted a lot of research interests in recent years.

Feature extraction is a crucial step for gait recognition. It usually comprises the tasks of feature construction, space dimensionality reduction, sparse representations and feature selection. The basic gait feature extraction methods are based on the parameters of human body, such as structural stride parameters (BenAbdelkader et al., 2002), joint angle trajectories (Tanawongsuwan & Bobick, 2001) and five-link biped model (Zhang et al., 2004). Some latterly proposed methods take the gait silhouette as a whole and extract low dimensional feature from it, such as unwrapping the contour into a set of boundary pixel points sampled along its outer-contour (Wang et al. 2003) and self- similarity plot (BenAbdelkader et al., 2004). Robust gait representation tends to be a new research field in gait recognition. The robust gait representation can be applied directly to gait recognition or used for further feature extraction. Han & Bhanu (2006) proposed gait energy image (GEI) to characterize human walking properties, which is an average image of a gait cycle. Gait history image (GHI) (Liu & Zheng, 2007) and gait moment image (GMI) (Ma et al., 2007) were developed based on GEI. GHI preserves the temporal information alongside width the spatial information. GMI is the gait probability image at each key moment of all gait cycles. Lee et al. (2007) introduced a novel spatiotemporal Shape Variation-Based Frieze Pattern (SVB frieze pattern) representation for gait. Lam et al. (2007) fused two templates, the motion silhouette contour templates (MSCTs) and static silhouette templates (SSTs) for gait recognition.

The foregoing gait feature or representation performs well under some circumstances. However, as for any pattern recognition problem, a single feature can not solve the gait recognition problem thoroughly. Information fusion technology offers a promising solution to the development of a superior classification system. It has been applied to numerous fields and new applications are being explored constantly. For gait recognition problem, information fusion is necessary to be employed under at least three circumstances.

Multiple **gait feature fusion**: Wang et al. (2004) employed both static and dynamic features for recognition using the nearest exemplar classifier. The features were fused on decision level using different combination rules. Lam et al. (2007) presented two gait feature representation methods, the motion silhouette contour templates (MSCTs) and static silhouette templates (SSTs), and performed decision-level fusion by summarizing the similarity scores. Bazin et al. (2005) examined the fusion of a dynamic feature and two static features in a probabilistic framework. They proposed a process for determining the probabilistic match scores using intra and inter-class variance models together with Bayes rule. Han & Bhanu (2004) proposed a method to learn statistical gait features from real templates and synthetic templates to address the problem of lacking gallery gait data. A matching score fusion strategy was therefore applied to improve the recognition performance. Veres et al. (2005) tried to fuse static and dynamic features to overcome the problem when the gallery and probe databases were recorded with a time interval. Generally speaking, superior gait recognition performance was reported when multiple features were employed.

Multiple view gait sequences fusion: While some research attempted the multiview gait recognition problem by warping the original views to the canonical view (Tyagi et al., 2006; Kale

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