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Intelligences of Fusing Face and Gait in Multimodal Biometric System: A Contemporary Study

Annbuselvi K [1], Santhi N [2]
Associate Professor
Department of Computer Science
V.V.V. College for Women (Autonomous), Virudhunagar,
Tamil Nadu - India

ABSTRACT
Multimodal Biometric system can be defined as one that integrates the result obtained from more than one human biometric feature for the purpose of identification. For remote recognition, a unimodal biometric system that may result in non-universality, a multimodal biometric system can result in highly accurate and secure biometric identification system. The recent research exposes that multi-modal biometric system is more effective in authentication. This paper analyses most recent face and gait fusion approaches, and the significant performance gains suggest these two modalities are complementary for human identification at a distance.
Keywords:— Biometric; multimodal; fusion; recognition

I. INTRODUCTION

Biometrics is automated methods of recognizing a person based on a physiological or behavioral characteristic. Among the features measured are; face, fingerprint, hand geometry, iris, retinal, signature, and voice. Biometric technologies are becoming the basis of a wide collection of highly secure identification and personal verification solutions. As the level of security breaches and transaction fraud increases, the need for highly secure identification and personal verification technologies is becoming obvious.

II. MULTIMODAL BIOMETRIC SYSTEMS

A. Vibrant of multimodal biometric systems

Authentication systems setup with one biometric modality may not be sufficient for the pertinent application in terms of properties such as universality, distinctiveness, acceptability etc. 100% accuracy may not achieve in unimodal systems on account of the limitations such as the noise in the sensor data, intra class variations, inter class similarities, lack of universality, interoperability issues, spoof attacks and other vulnerabilities. Multimodal biometric system is a refined system of unimodal system incorporating the remedial measures for the drawbacks faced in unimodal biometric system.

A multimodal biometrics refers to the use of a combination of two or more biometric modalities (see Fig. 1) in verification/identification system. Identification based on multiple biometrics represents an emerging trend. This can be done when biometric features of different biometrics are statistically independent. The most forceful reason to combine independent modalities is to improve the recognition rate. In recent decades, intelligent surveillance is becoming more and more important in the fields of public security.

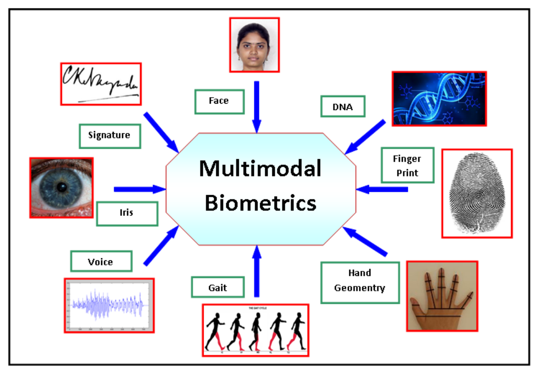

Figure 1: Modalities used for multimodal biometric system

As an active research topic in computer vision, visual surveillance in dynamic scenes attempts to detect, track and recognize certain objects from video sequences, and more generally to understand and describe them. For its wide application foreground and great potential economic value, recognition of individuals is attracting more and more interest of researchers all over the world.

III. FUSING GAIT AND FACE FOR HUMAN RECOGNITION

B. Face recognition

Employing the face for recognition in domains such as surveillance, covert security and context-aware environments presents some difficulties since the appearance of the face can be altered by intrinsic factors such as age, expression, facial paraphernalia (facial hair, glasses, cosmetics, etc.), ethnicity, and gender as well as extrinsic ones such as illumination, pose, scale and imaging parameters (e.g., resolution, focus, imaging noise, etc.).

C. Gait recognition

Gait is a behavioral biometric, whose utility for human recognition has only recently begun to be explored. Similar to the face, gait, too, is a visual cue which can be extracted from video and thus, it appears to offer the same advantages (outlined above) that are presented by the face. However, gait offers some additional benefits in that, unlike the face, it can be acquired from a sequence of low resolution images of a person taken from a distance where the subject's body occupies too few pixels for other biometric traits to be discerned. Moreover, it is more robust to slight variations in viewpoint as compared to other biometrics and cannot be easily disguised without attracting attention.

Nevertheless, gait as a biometric has its limitations since, being a behavioral trait, it can be affected and altered by factors such as clothing, footwear, environmental conditions, emotions, fatigue, drunkenness, pregnancy, injury, disease, aging and load. In addition, gait also suffers from the usual problems associated with extracting visual cues from video such as imperfect foreground segmentation of the walking subject from the background scene, and poor imaging conditions.

D. Provocation for fusing face and gait for human recognition

Vision-based human identification from a distance is a promising technology for access control and crime prevention in security sensitive environments such as secret department, banks, and airports. At a distance, many typical physiologic features, such as iris, fingerprint and DNA, are obscured or cannot be obtained at all. By contrast, both gait and face can usually be obtained from most video surveillance systems. Hence in the task of human recognition at a distance, it is a potential approach to fuse face and gait which can be acquired from the same or multiple sensors.

IV. LEVELS OF MULTIMODAL BIOMETRIC FUSION

Based on the type of information available, different levels of fusion may be defined. Sanderson and Paliwal [1] categorise the various levels of fusion (see Fig. 2) into two broad categories: pre-classification or fusion before matching, and post classification or fusion after matching.

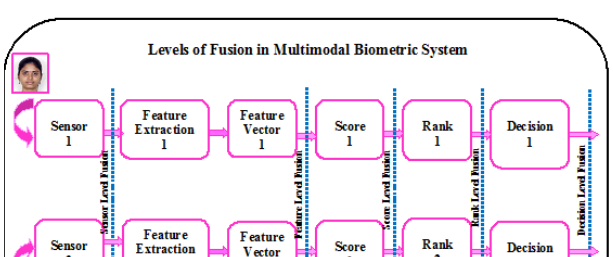

Figure 2: Various levels of multimodal biometric fusion

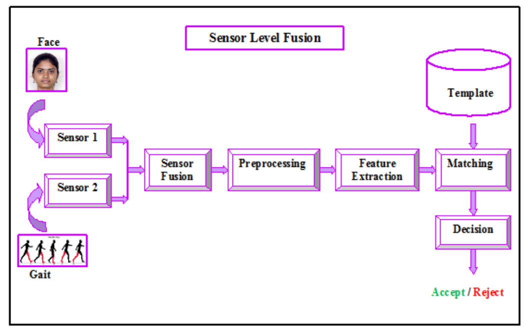

Figure 3: Sensor level fusion

The latter has been attracting a lot of attention since the amount of information available for fusion reduces drastically once the matcher has been invoked. Pre-classification schemes include fusion at the sensor and the feature levels while post-classification schemes include fusion at the match score, rank and decision levels.

A survey of integrated face-gait recognition techniques has, therefore, been undertaken in this paper. In order to obtain optimal performance, a fusion system, which combines face and gait cues obtained from video sequences, is a practical approach to accomplish the task of human identification.

E. Sensor-level fusion

The raw data (e.g., a face image) acquired from an individual represents the richest source of information although it is expected to be contaminated by noise (e.g. non-uniform illumination, background clutter, etc.). Sensor-level fusion refers to the consolidation of (a) raw data obtained using multiple sensors (see Fig. 3), or (b) multiple snapshots of a biometric using a single sensor.

G. Shakhnarovich, L. Lee and T. Darrell [2] developed a view-normalization approach to multi-view face and gait recognition. For optimal face, they placed virtual cameras to capture frontal face appearance; for gait they placed virtual cameras to capture a side-view of the person. Multiple cameras can be rendered simultaneously, and camera position is dynamically updated as the person moves through the workspace. Image sequences from each canonical view are passed to an unmodified face or gait recognition algorithm.

Ju Han, Bir Bhanu [3] proposed a hierarchical scheme to automatically find the correspondence between the preliminary human silhouettes extracted from synchronous color and thermal image sequences for image registration and discussed strategies for probabilistically combining cues from registered color and thermal images for improved human silhouette detection

F. Feature Level Fusion

In feature-level fusion the feature sets originating from multiple feature extraction algorithms are consolidated into a single feature set (see Fig. 4) by the application of appropriate feature normalization, transformation and reduction schemes. The primary benefit of feature-level fusion is the detection of correlated feature values generated by different feature extraction algorithms and, in the process, identifying a salient set of features that can improve recognition accuracy. Eliciting this feature set typically requires the use of dimensionality reduction/selection methods and, therefore, feature-level fusion assumes the availability of a large number of training data.

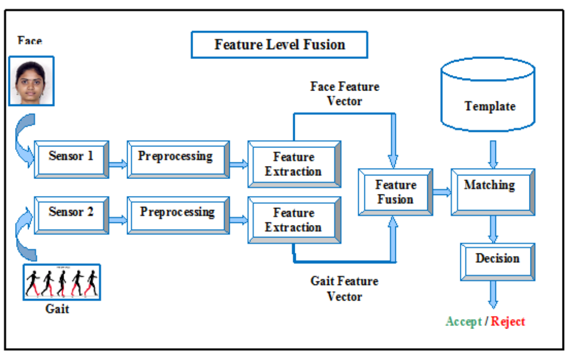

Figure 4: Feature level fusion

Xiaoli Zhou and Bir Bhanu [4] suggested a new approach at feature level. The features of face and gait are obtained separately using principal component analysis (PCA) from enhanced side face image (ESFI) and gait energy image (GEI), respectively. Multiple discriminant analysis (MDA) is employed on the concatenated features of face and gait to obtain discriminating synthetic features and they demonstrated the better performance of their fusion scheme.

Caifeng Shan, Shaogang Gong, Peter W. McOwan[5] exploited a tool named canonical correlation analysis (CCA), for relating two sets of measurements, to fuse the two modalities face and gait at the feature level and showed better recognition performance of 97%.

Li Qi-Shen Lu Zhi-Tian Zhang Dan-Dan [6] presented a new approach, where feature extraction and dimension reducing is done to Gait Energy Image (GEI) and Side Face Image (SFI) respectively by 2DIMPCA, and two original feature vectors are obtained correspondingly, which are integrated into synthetic feature vectors. Then MDA is employed on the synthetic feature vectors of gait and side face to obtain fusion features vectors. Finally, the recognition process is implemented on the fusion feature vectors by nearest neighbor (NN) algorithm.

Emdad Hossain and Girija Chetty [7] proposed an approach for ascertaining human identity based on fusion of profile face and gait biometric cues based on feature learning in PCA-LDA subspace, and classification using multivariate Bayesian classifiers for low resolution surveillance video scenarios.

Manhal Saleh Almohammad, Gouda Ismail Salama and Tarek Ahmed Mahmoud [8] developed a method to fuse frontal of face and side of gait at feature level. Face image is represented by the Active Lines among Face Landmark Points (ALFLP) feature vector.

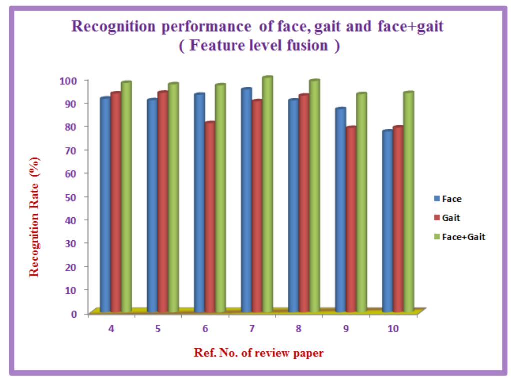

Figure 5: Recognition performance – Feature Level

Gait image is represented by the Active Horizontal Levels (AHL) feature vector. The feature vectors are fused using the eigen vector, representing the fusion features vector used for healthier classification.

De Zhang, Yunhong Wang, Zhaoxiang Zhang, Maodi Hu [9] proposed a method to combine frontal face and lateral gait, for the specific problem of ethnicity classification at feature level. Face features are extracted by means of the uniform LBP operator and gait is characterized by a spatio-temporal representation. CCA used to fuse the two modalities at the feature level to improve ethnicity recognition rate.

Xianglei Xing, Kejun Wang and Zhuowen Lv [10] proposed coupled projections based method first maps the heterogeneous features from gait and face into a unified subspace to minimize the distance between the two features. The fusion features are obtained by computing the mean of the two projecting features from the same person in the coupled subspace to show healthier recognition rate.

The recognition performance results of reviewed papers are shown in Fig. 5.

G. Score-level fusion

At this level, the match scores output by multiple experts are combined (see Fig. 6) to generate a new output (a scalar or vector) that can be subsequently used for decision-making. Fusion at this level is the most commonly discussed approach primarily due to the ease of accessing and processing match scores (compared to the raw data or the feature set extracted from the data).

Gregory Shakhnarovich Trevor Darrell [11] developed a probabilistic approach to integrate face and gait at score level. The best performance was obtained by a classifier that uses product of the posterior probabilities estimated from different modalities.

Xin Geng, Liang Wang, Ming Li, Qiang Wu, and Kate Smith-Miles [12, 13] proposed an adaptive fusion to combine gait and face for human identification, which dynamically adjusts the fusion rules to suit the real-time external conditions. Experimental results show that distance-driven fusion performs better than the conventional static fusion rules.

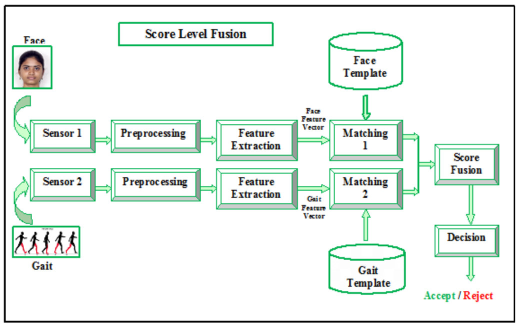

Figure 6: Score level fusion

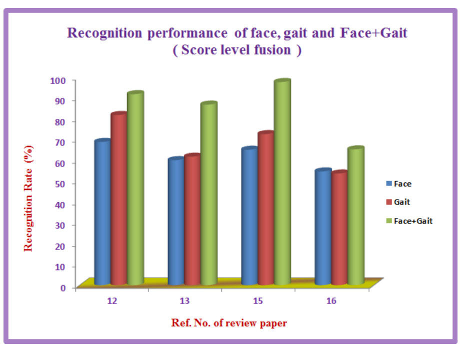

Figure 7: Recognition performance - Score Level

Tracey K. M. Lee, Surendra Ranganath , Saeid Sanei [14] showed that frontal-normal motion analysis yields more dynamic information as compared to fronto-parallel motion for gait and face in a nonideal environment to integrate at score level for better recognition accuracy.

Ali Pour Yazdanpanah, Karim Faez and Rasoul Amirfattahi [15] proposed a novel technique using three modalities including face, ear and gait, based on Gabor+ PCA feature extraction method with fusion at matching score level and achieved 97.5% of recognition rate.

Martin Hofmann, Stephan M. Schmidt, AN. Rajagopalan and Gerhard Rigoll [16] developed a new automated segmentation technique based on alpha-matting for gait and for low-resolution facial profile images and fused at score level to show significant recognition performance.

Yu Guan, Xingjie Wei, Chang-Tsun Li, Gian Luca Marcialis, Fabio Roli, Massimo Tistarelli [17] proposed a multimodal-RSM framework for gait feature and kernel Fisher analysis (KFA) method for face feature extraction and fused at score level to show better recognition result.

Takuhiro Kimura, Yasushi Makihara, Daigo Muramatsu, Yasushi Yagi [18] considered spatial resolution (SR) and temporal resolution (TR) as quality measures that simultaneously affect the scores of individual modalities and showed performance evaluation results both for quality independent and quality-dependent score-level fusion.

The recognition performance results of reviewed papers are shown in Fig. 7.

H. Rank-level fusion

This type of fusion is relevant in identification systems where each classifier associates a rank with every enrolled identity (a higher rank indicating a good match). Thus, fusion entails consolidating the multiple ranks associated with an identity and determining a new rank that would aid in establishing the final decision

Monwar and Gavrilova developed a multimodal biometric system utilizing face, ear and signature biometric identifiers [19]. They proposed rank fusion approaches for biometric fusion using fisher image method as matching algorithm and logistic regression and Borda count for fusing rank information. Very few methods for consolidation of biometric rank information can be found in the literature, as it is still

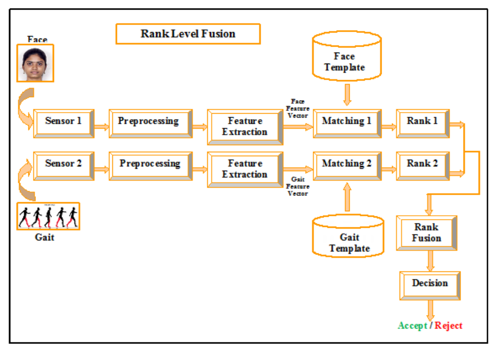

Figure 8: Rank level fusion

I. Decision-level fusion

Fusion may also be carried out on the final decisions obtained for each mono biometric process (see Fig. 9) through the use of some kind of Boolean function. The most frequent algorithms used in this type of fusion are AND, OR and VOTING.

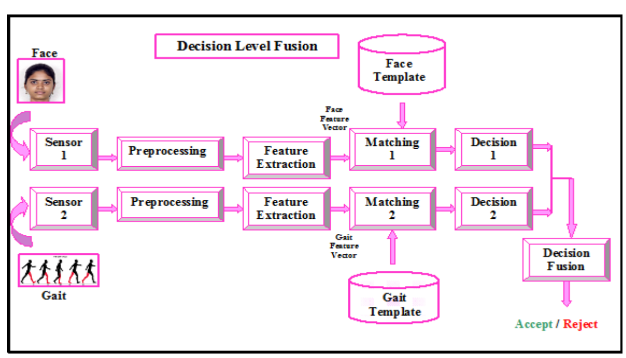

Figure 9: Decision level fusion

Amit Kale, Amit K. RoyChowdhury and Rama Chellappa [20], employed decision fusion to combine face and gait in two fusion scenarios: hierarchical and holistic. The first uses gait recognition algorithm as a filter to pass on a smaller set of candidates to the face recognition and the second combines the similarity scores of face and gait to show higher recognition result.

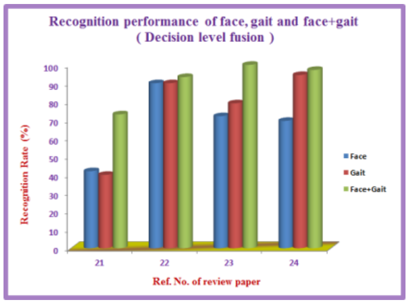

Figure 10 : Recognition performance - Decision Level

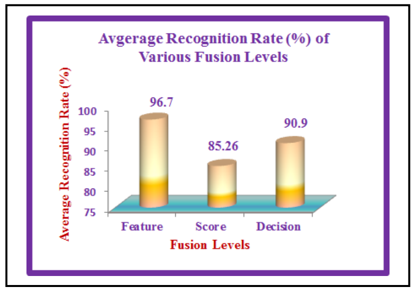

Figure 11

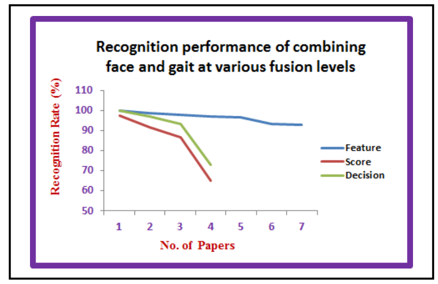

Figure 12

Table 1: **Recent Works on Fusing Face and Gait for human identification at a distance**

Year	Author	Biometrics fused	Fusion level	Fusion technique used
2007	Xiaoli Zhou, BirBhanu	Side Face, Gait	Feature	Normalized low dimensional side face feature and gait feature are concatenated using MDA for fusion
2009	Li Qi-Shen, Lu Zhi-Tian, Zhang Dan-Dan	Side Face, Gait	Feature	Face and Gait features obtained by using 2DIMPCA are fused by Multiple Discriminant Analysis (MDA)
2012	Manhal Saleh Almohammad, Gouda Ismail Salama, Tarek Ahmed Mahmoud	Frontal Face, Side Gait	Feature	Face feature vector obtained by using Active Lines among Face Landmark Points(ALFLP) and gait feature vector obtained by using ActiveHorizontal Levels (AHL) are fused
2012	De Zhang, Yunhong Wang, Zhaoxiang Zhang, Maodi Hu	frontal face, lateral gait	Feature	Face feature obtained by using Uniform Local Binary Pattern and Gait feature obtained by Spatio-temporal are fused by using Canonical Correlation Analysis
2015	Xianglei Xing, Kejun Wang, ZhuowenLv	Face, Gait	Feature	The weighted mean of two projective points of face and gait features are coupled for fusion
2011	Emdad Hossain, Girija Chetty,	Face, Gait	Feature	LDA transformed features of face and gait are fused and classification is done by using multivariate Bayesian classifiers
2008	Caifeng Shan, Shaogang Gong, Peter W. McOwan,	Face, Gait	Feature	The two modalities are fused by using canonical correlation analysis (CCA) tool
2010	Ali Pour Yazdanpanah, Karim Faez , Rasoul Amirfattahi,	Face, Gait	Score	Features are extracted by using Gabor+ PCA method and match score values are fused by weighted sum and weighted product
2012	Martin Hofmann, Stephan M. Schmidt, AN. Rajagopalan, Gerhard Rigoll,	Face, Gait	Score	Score values of two feature sets obtained by using Alpha Matte preprocessing method are fused using SUM, PRODUCT and MAX
2013	Yu Guan, Xingjie Wei, Chang-Tsun Li, Gian Luca Marcialis, Fabio Roli, Massimo Tistarelli,	Face, Gait	Score	Two feature sets obtained by using RSM framework for gait and kernel Fisher analysis method for face and the score values are fused by using weighted sum
2015	Takuhiro Kimura, Yasushi Makihara, Daigo Muramatsu, Yasushi Yagi,	Face, Gait	Score	Spatial resolution (SR) and temporal resolution (TR) quality independent and dependent measures of gait, head, and the height biometrics from a single walking image sequence scores are fused.
2004	Amit Kale, Amit K. RoyChowdhury, Rama Chellappa,	Face, Gait	Decision	The gait classifier result is used as a filter to pass a smaller number of candidates to face recognition unit and conventional fusion rules SUM, PRODUCT etc. are used
2007	Zongyi Liu, Sudeep Sarkar,	Face, Gait	Decision	Hidden Markov Model (HMM) for gait and elastic bunch graph matching method for face and fused at score level and decision level
2016	Asma El Kissi Ghalleb, Riwa Ben Slamia, Najoua Essoukri Ben Amara,	Face, Gait	Decision	Exploration of two soft modalities of the face and six soft modalities of the body are fused by using the technique of majority voting
2008	De Zhang, Yun-Hong Wang	Face, Gait	Decision	PCA for face classification and for gait classification, they divide the silhouette into seven parts and extract features from each and SVM classifier is used for gender recognition

Zongyi Liu, Sudeep Sarkar[21], developed a new method which identifies the salient stances using a population hidden Markov model (HMM) for gait and elastic bunch graph matching method for face and fused at score level and decision level recognition for better performance.

De Zhang, Yun-Hong, Wang [22] introduced PCA for face classification and for gait classification, they divide the silhouette into seven parts and extract features from each and employ SVM to classify gender at decision level.

Asma El Kissi Ghalleb1 Riwa Ben Slamia2 Najoua Essoukri Ben Amara [23] proposed a decision level fusion method based on fusing two soft modalities of the face, which are the skin and hair colors, and six soft modalities of the body – one for the height, four for the body measurements, and one for gait cycle and showed 95 % of recognition rate.

Ying-hui Kong, Pei-yao Chen [24], propose an adaptive decision level fusion method of face and gait, firstly they used the gait energy image for gait and Haar classifier for face. They used nonlinear programming for fusing to achieve the best information fusion results.

The recognition performance results of reviewed papers are shown in Fig.10. Average Recognition performance and Recognition performance at various fusion levels of reviewed papers are shown in Fig. 11 and Fig. 12. Table 1 represents summary of previous works on fusion of gait and face for human identification at a distance.

V. CONCLUSION

In this paper, we presented an overview of the current trends in face and gait fusion approaches for human identification at a distance and observed an optimal recognition performance rate when gait and face modalities are combined. Experimental results shows that feature level fusion gives the best performance compared to decision level fusion and score level fusion, while the performance of decision level fusion is better than score level fusion.

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