CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 INTRODUCTION

Interface of computer technologies and biology is having a huge impact on society. Human recognition technology research project promises new life to many security consulting firms and personal identification system manufacturers. The physiological or biological features of an individual, called biometrics, are unique to each human and remain unaltered during a person's lifetime and give a promising solution for security management. The most momentous and recent advancement in biometrics has been the development of multimodal biometric systems. Over the last decade, multimodal biometrics has been developed into one of the most potent and fastest growing technologies in the field of biometrics. The incessant emergence of multimodal biometric systems in recent times has necessitated a review of the latest trends in multimodal biometric systems. The review will be extremely valuable for guiding or selecting the appropriate biometric traits and fusion strategies for designing multimodal biometric systems. The foci of this chapter are on providing a summarization of important and advanced recognition methods on face, palmprint, fingerprint and touchless fingerprint as well as multimodal biometric systems.

2.2 MULTIMODAL BIOMETRIC SYSTEMS

Unimodal biometric systems have to contend with a variety of problems such as noisy data, intra-class variations, restricted degrees of freedom, non-universality, spoof attacks, and unacceptable error rates. Some of these limitations can be addressed by deploying multimodal biometric systems that integrate the evidence presented by multiple sources of information. A number of multimodal biometric systems have been proposed in literature that differ from one another in terms of their architecture, the number and choice of biometric modalities, the level at which the evidence is accumulated, and the methods used for the integration or fusion of information. A brief review of some recent multimodal biometric systems has been presented in this section.

Gian Luca Marcialis *et al*. [112] have described the use of personal identity verification systems with multi-modal biometrics, in order to increase the performance and robustness against environmental variations and fraudulent attacks. Usually multi-modal fusion of biometrics was performed in parallel at the score-level by combining the individual matching scores. Their parallel strategy exhibits some drawbacks: (i) all available biometrics were necessary to perform fusion, thus the verification time depends on the slowest system; (ii) some users could be easily recognizable using a certain biometric instead of another one and (iii) the system invasiveness increases. A system characterized by the serial combination of multiple biometrics can be a good trade-off between verification time, performance and acceptability. However, those systems have been poorly investigated, and no support for designing the processing chain has been given so far. In their paper, they propose a novel serial scheme and a simple mathematical model able to predict the performance of two serially combined matches as function of the selected processing chain. Our model helps the designer in finding the processing chain allowing a trade-off, in particular, between performance and matching time. Experiments carried out on well-known benchmark data sets made up of face and fingerprint images support the usefulness of the proposed methodology and compare it with standard parallel fusion.

Raghavendra *et al*. [113] have described the Reliable user identification which was a common requirement for almost every secure system. Biometric offer a natural and reliable solution to certain aspects of identity management by recognizing the individuals based on their inherent physical and behavior characteristics. Multimodal biometric person verification was gaining much popularity in recent years as they outperform unimodal person verification. Their paper presents a person verification system using speech and face data. The verification system comprises of two classifiers whose scores were fused using sum rule after normalization. The experiments were carried out on VidTIMIT database. The experimental results show that face expert designed using Two-Dimensional Linear Discriminate Analysis and speech expert using Linear Prediction Cepstral Coefficients as feature extractor and Gaussian Mixture Model as opinion generator with 16 mixtures will provide a Half Total Error Rate of 1.2%.

Uma Maheswari and Anbalagan [114] have described an intelligent multimodal biometric verification system for physical access control, based on fusion of iris, face and fingerprint patterns. Feature vectors were created independently for query images and are then compared with the enrolled templates of each biometric trait to compute the matching score. The final decision was made by fusion at their matching score level.

Their proposed system was designed to suit embedded solutions for high security access in pervasive environments using biometric features.

Mohamed Soltane *et al*. [115] have proposed the use of finite Gaussian Mixture Modal (GMM) based Expectation Maximization (EM) estimated algorithm for score level data fusion. Automated biometric systems for human identification measure a "signature" of the human body, compare the resulting characteristic to a database, and render an application dependent decision. Those biometric systems for personal authentication and identification were based upon physiological or behavioral features which were typically distinctive, Multi-biometric systems, which consolidate information from multiple biometric sources, are gaining popularity because they were able to overcome limitations such as non-universality, noisy sensor data, large intra-user variations and susceptibility to spoof attacks that are commonly encountered in mono modal biometric systems. Simulation shows that Finite Mixture Modal (FMM) was quite effective in modelling the genuine and impostor score densities, fusion based the resulting density estimates achieves a significant performance on eNTERFACE 2005 multi-biometric database based on face and speech modalities.

Rufeng Chu *et al*. [116] have presented a face and palmprint multimodal biometric identification method and system to improve the identification performance. Effective classifiers based on ordinal features were constructed for faces and palmprints, respectively. Then, the matching scores from the two classifiers were combined using several fusion strategies. Experimental results on a middle-scale data set have demonstrated the effectiveness of their proposed system.

Dakshina Ranjan Kisku *et al*. [117] have presented a feature level fusion approach which uses the improved K-medoids clustering algorithm and isomorphic graph for face and palmprint biometrics. Partitioning Around Medoids (PAM) algorithm was used to partition the set of n invariant feature points of the face and palmprint images into k clusters. By partitioning the face and palmprint images with scale invariant features SIFT points; a number of clusters were formed on both the images. Then on each cluster, an isomorphic graph was drawn. In their next step, the most probable pair of graphs was searched using iterative relaxation algorithm from all possible isomorphic graphs for a pair of corresponding face and palmprint images. Finally, graphs were fused by pairing the isomorphic graphs into augmented groups in terms of addition of invariant SIFT points and in terms of combining pair of key point descriptors by concatenation rule. Experimental results obtained from the extensive evaluation show that the proposed feature level fusion with the improved K-medoids partitioning algorithm increases the performance of the system with utmost level of accuracy.

Most existing face and iris fusion schemes are concerned about improving performance on good quality images under controlled environments. Xiaobo Zhang *et al*. [118] have proposed a hierarchical fusion scheme for low quality images under uncontrolled situations. In the training stage, canonical correlation analysis (CCA) was adopted to construct a statistical mapping from face to iris in pixel level. In their testing stage, firstly the probe face image was used to obtain a subset of candidate gallery samples via regression between the probe face and gallery irises, then ordinal representation and sparse representation are performed on these candidate samples for iris recognition and face recognition respectively. Finally, score level fusion via min-max normalization was performed to make final decision. Experimental results on our low quality database show the outperforming performance of their proposed method.

Due to the increase in security requirements, biometric systems have been commonly utilized in many recognition applications. Multimodal has great demands to overcome the issue involved in single trait system and it has become one of the most important research areas of pattern recognition. Muhammad Imran Razzak *et al*. [119] have proposed multimodal face and finger veins biometric verification system to improve the performance. They presented multilevel score fusion of face and finger veins to provide better accuracy. Simulation result shows that proposed multimodal recognition system was very efficient to reduce the false rejection rate.

Lorenzo Luciano and Adam Krzyżak [120] have presented an automated multimodal biometric system for the detection and recognition of humans using face and ear as input. Their system was totally automated, with a trained detection system for face and for ear. They look at individual recognition rates for both face and ear, and then at combined recognition rates, and show that an automated multimodal biometric system achieves significant performance gains. They also discuss methods of combining biometric input and the recognition rates that each achieves.

Audrey Poinsot *et al.* [58] have described that the Contactless biometrics provide high comfort and hygiene in person recognition. Because of their approach, such systems were better accepted by the general public. Their paper proposes an adaptive, contactless, biometric system which combines two modalities: palmprint and face. The processing chain has been designed to overcome embedded system constraints and small sample set problem: after a palmprint was extracted from a hand image, Gabor filters were applied to both the palmprint and face in order to extract parameters, which was then used for classification. Fusion possibilities were also discussed and tested using a multimodal database of 130 people designed by the authors. High recognition performance has been obtained by respecting embedded system context, with palmprint only and with fusion of palmprint and face: recognition rates of respectively 96.39% and 98.85% are achieved using only 2 samples per modality. Therefore their preliminary study shows the feasibility of a robust and efficient multimodal hardware biometric system.

Vincenzo Conti *et al.* [61] have proposed a multimodal biometric system by means of two different fingerprints. In order to match score fusion, the matching module integrates a fuzzy logic methods. Experimentation using both decision level fusion and matching score level fusion are being done. The obtained results showed an improvement of 6.7% using the matching score level fusion rather than a mono-modal authentication system. Ricardo N. Rodrigues *et al.* [62] have proposed two fusion schemes that can enhance the security of multimodal biometric systems. While one of the modes was successfully spoofed, they were able to address the security of multimodal biometric systems. The formal one used an extension of the likelihood ratio based fusion scheme and the later one used fuzzy logic. In spite the matching score and sample quality score, the proposed fusion schemes also take into account the intrinsic security of each biometric system. Experimental results have shown that the proposed methods were more robust against spoof attacks when compared with traditional fusion methods.

Henry Pak-sum Hui *et al.* [63] have described a multi-biometric verification system that was fully adaptive to variability in data acquisition using fuzzy logic decision fusion. The system used the fuzzy logic to dynamically alter the weight of three biometrics (face, fingerprint and speech), taking into account the variations during data acquisition (e.g. lighting, noise and user-device interactions). A specific decision boundary was determined by this dynamic weight assignment in order to make the authentication decisions. An overall EER improvement of 42.1 % relative to weighted average fusion has been attained.

Md. Maruf Monwar *et al.* [64] have presented an effective fusion scheme that combined information presented by multiple domain experts based on the rank-level fusion integration method. The developed multimodal biometric system possesses a number of unique qualities, starting from utilizing principal component analysis and Fisher's linear discriminant methods for individual matchers (face, ear, and signature) identity authentication and utilizing the rank-level fusion method in order to consolidate the results obtained from different biometric matchers. The ranks of individual matchers were combined using the highest rank, Borda count, and logistic regression approaches. The results indicate that fusion of individual modalities improves the overall performance of the biometric system, even in the presence of low quality data.

Lin Huang *et al.* [65] have proposed a method to fuse information from two or more biometric sources at feature fusion level. A key aspect of the method was to use an optimization procedure to regulate the contribution of each individual biometric modality to the concatenated feature vector. As an example, the effectiveness of the method was demonstrated by integrating features of static face images and text-independent speech segments. Experiments in feature-level fusion were carried out for 40 subjects from a virtual database consisting of face images and speech clips. The results showed that the proposed method outperforms both the system without feature fusion and those based on intuition feature fusion.

Donald E. Maurer and John P. Bakera [66] have developed a fusion architecture based on Bayesian belief networks. Although Bayesian update methods have been used before, their approach more fully exploited the graphical structure of Bayes nets to define and explicitly model statistical dependencies between relevant variables: per sample measurements, such as match scores and corresponding quality estimates, and global decision variables. Those statistical dependencies were in the form of conditional distributions which they model as Gaussian, gamma, log-normal or beta, each of which was determined by its mean and variance, thus significantly reducing training data requirements. Moreover, by conditioning decision variables on quality as well as match score, they extracted information from lower quality measurements rather than rejecting them out of hand. Another feature of the proposed method was a global quality measure designed for using as a confidence estimate supporting decision making. Preliminary studies using the architecture to fuse fingerprints and voice were reported

Ajita Rattani and Massimo Tistarelli [67] have presented an approach for feature level fusion of multi-modal and multi-unit sources of information. For multi-modal fusion the face and iris biometric traits were considered, while the multi-unit fusion was applied to merge the data from the left and right iris images. The proposed approach computed the SIFT features from both biometric sources, either multi-modal or multi-unit. For each source, feature selection on the extracted SIFT features was performed via spatial sampling. Then those selected features were finally concatenated together into a single feature super-vector using serial fusion. The concatenated super feature vector was used to perform classification. Experimental results from face and iris standard biometric databases were presented. The reported results clearly showed the performance improvements in classification obtained by applying feature level fusion for both multi-modal and multi-unit biometrics in comparison to unimodal classification and score level fusion.

Sheetal Chaudhary and Rajender Nath [68] have presented a multimodal biometric recognition system integrating palmprint, fingerprint and face based on score level fusion. The feature vectors were extracted independently from the pre-processed images of palmprint, fingerprint and face. The feature vectors of query images were then compared individually with the enrollment templates which were taken and stored during database preparation for each biometric trait respectively. The individual matching scores generated after matching of query images with database images were passed to the fusion module. Fusion module performed score normalization and fusion of normalized scores by weighted sum rule. Those individual normalized scores along with their weights were finally combined into a total score by sum rule, which was passed to the decision module which declares the person as genuine or an imposter. The proposed multimodal biometric system overcome the limitations of individual biometric systems and also met the response time as well as the accuracy requirements.

F. Wang and J. Han [69] have presented a multimodal biometric authentication method integrating face and iris based on score level fusion. For score level fusion, support vector machine (SVM) based fusion rule was applied to combine two matching scores, respectively from Laplacian face based face verifier and phase information based iris verifier, to generate a single scalar score which was used to make the final decision. Experimental results showed that the performance of the proposed method achieved obvious improvement comparing to the unimodal biometric identification methods. Byung Jun Kang and Kang Ryoung Park [70] have proposed a multimodal biometric recognition based on the fusion of finger vein and finger geometry. This is the first approach to combine the finger vein and finger geometry information at the same time. Second, the proposed method included a finger geometry recognition based on the sequential deviation values of finger thickness extracted from a single finger. Third, they integrated finger vein and finger geometry by a score-level fusion method based on a support vector machine. Results showed that recognition accuracy was significantly enhanced using the proposed method.

Haijun Zhang *et al.* [71] have discussed a multi-modal biometrics based on face and ear. The research significance of multi-modal biometrics based on face and ear was represented first, and then they introduced some researchers' achievements and inadequacies. They also propose further exploration and research in this area. Ching-Han Chen and Chia Te Chu [72] have developed a multimode biometric approach, which was able to diminish the drawback of single biometric approach as well as to improve the performance of authentication system. They combined a face database ORL and iris database CASIA to construct a multimodal biometric experimental database with which they validated the proposed approach and evaluated the multimodal biometrics performance. The experimental results revealed that the multimodal biometrics verification was much more reliable and precise than single biometric approach.

Zongyi Liu and Sudeep Sarkar [73] have presented the possibility of using both face and gait in enhancing human recognition at a distance performance in outdoor conditions. For gait, they presented a recognition scheme that relies on computing distances based on selected, discriminatory, gait stances. For face, which is a mature biometric for which many recognition algorithms exist, they chose the elastic bunch graph matching based face recognition method. This method was found to be the best in the FERET 2000 studies. Specifically, for data taken on the same day, individual verification rates were 42% and 40% for face and gait, respectively, but for their combination, the rate was 73%. Similarly, for the data taken with at least 3 months apart, the verification rate was 48% and 25% for face and gait, respectively, but for their combination, the rate was 60%. They also found that the combination of outdoor gait and one outdoor face per person was superior for using two outdoor face probes per person or using two gait probes per person, which was considered to be statistical controls for showing improvement by biometric fusion.

2.3 FACE RECOGNITION SYSTEMS

Face recognition has received substantial attention from researchers in biometrics, computer vision, pattern recognition, and cognitive psychology communities because of the increased attention being devoted to security, man-machine communication, content-based image retrieval, and image/video coding. As one of the most important biometric techniques, face recognition has clear advantages of being natural and passive over other biometric techniques requiring cooperative subjects such as fingerprint recognition and iris recognition. Here, we have presented some of the significant researches for face recognition.

Xiao-ning Song *et al.* [93] made extensive studies on the essence of fuzzy linear discriminant analysis (F-LDA) algorithm and fuzzy support vector machine (FSVM) classifier, respectively. Still, a serious disadvantage of FSVM is that the computation requisite increases proportionally with the increase in number of classes and training sample size. To solve the above said issue, a more improved technique of FSVM method that combines the advantages of FSVM and decision tree, called DT-FSVM, was formulated. Additionally, in the feature extraction process, a reformative F-LDA algorithm based on the fuzzy k-nearest neighbors (FKNN) is implemented to gain the distribution information of each and every original sample symbolized with fuzzy membership grade, which was incorporated into the redefinition of the scatter matrices. They produced F-LDA algorithm with the aid of a relaxed normalized condition in the description of fuzzy membership function. Towards the end, by making full use of the fuzzy set theory, a complete F-LDA (CF-LDA) framework was formed by merging the reformative F-LDA (RF-LDA) feature extraction method along with DT-FSVM classifier. There by making use of this hybrid fuzzy algorithm in face recognition problem many extensive experimental studies were conducted on the ORL and NUST603 face images databases that demonstrated the effectiveness of the proposed algorithm.

Mittal, N. and Walia, E. [94] introduced a fast PCA based face recognition algorithm. In their work, the database is sub grouped by taking account of some characteristics on faces. Among these a particular subgroups is provided to PCA for recognition. The efficiency of the proposed algorithm is verified using Indian face database, and the gained results prove an improvement in performance of the proposed algorithm as compared to the same with PCA method.

Al-Amin Bhuiyan and Chang Hong Liu [95] has dealt with an algorithm for face recognition using neural networks trained by Gabor features. The system was originated on convolving a face image with a series of Gabor filter coefficients at different scales and orientations. Scaling of rms (root mean square) contrast and origin of fuzzily skewed filter are the core area under considerations. The neural network made use for face recognition is on the basis of multilayer perceptron (MLP) architecture with back propagation algorithm and incorporates the convolution filter response of Gabor jet. The efficiency of this algorithm is justified over a face database with images captured at various illumination conditions.

Gandhe *et al*. [96] have described a contour matching based face recognition system, which uses “contour” for identification of faces. The feasibility of using contour matching for human face identification was presented through experimental investigation. The advantage of using contour matching is that the structure of the face was strongly represented in its description along with its algorithmic and computational simplicity that makes it suitable for hardware implementation. The input contour was matched with registered contour using simple matching algorithms. The proposed algorithm was tested on BioID face database and recognition rate was found to be 100%. Their proposed system of face recognition may be applied in identification systems, document control and access control.

Mohamed El Aroussi *et al*. [97] have described an efficient local appearance feature extraction method based on Steerable Pyramid (S-P) wavelet transform for face recognition. Local information was extracted by computing the statistics of each sub-block obtained by dividing S-P sub-bands. The obtained local features of each sub-band were combined at the feature and decision level to enhance face recognition performance. The purpose of their paper was to explore the usefulness of S-P as feature extraction method for face recognition. Their proposed approach was compared with some related feature extraction methods such as principal component analysis (PCA), as well as linear discriminant analysis LDA and boosted LDA. Different multi-resolution transforms, wavelet (DWT), Gabor, curvelet and contourlet were also compared against the block-based S-P method. Experimental results on ORL, Yale, Essex and FERET face databases convince us that the proposed method provides a better representation of the class information, and obtains much higher recognition accuracies in real-world situations including changes in pose, expression and illumination.

Marios Kyperountas *et al*. [98] have presented a novel face recognition algorithm that uses dynamic training in a multistage clustering scheme and evaluated. Their algorithm uses discriminant analysis to project the face classes and a clustering algorithm to partition the projected face data, thus forming a set of discriminant clusters. Then, an iterative process creates subsets, whose cardinality was defined by an entropy-based measure, that contain the most useful clusters. The best match to the test face was found when only a single face class was retained. Their method was tested on the ORL, XM2VTS and FERET face databases, whereas the UMIST database was used in order to train the proposed algorithm. Experimental results indicate that the proposed framework provides a promising solution to the face recognition problem.

Gabor features have been known to be effective for face recognition. However, only a few approaches utilize phase feature and they usually perform worse than those using magnitude feature. To investigate the potential of Gabor phase and its fusion with magnitude for face recognition, Shufu Xie *et al*. [99] have proposed local Gabor XOR patterns (LGXP), which encodes the Gabor phase by using the local XOR pattern (LXP) operator. Then, they introduced block-based Fisher's linear discriminant (BFLD) to reduce the dimensionality of their proposed descriptor and at the same time enhance its discriminative power. Finally, by using BFLD, they fuse local patterns of Gabor magnitude and phase for face recognition. We evaluate our approach on FERET and FRGC 2.0 databases. In particular, we perform comparative experimental studies of different local Gabor patterns. They also make a detailed comparison of their combinations with BFLD, as well as the fusion of different descriptors by using BFLD. Extensive experimental results verify the effectiveness of their LGXP descriptor and also show that their fusion approach outperforms most of the state-of-the-art approaches.

In the literature of psychophysics and neurophysiology, many studies have shown that both global and local features are crucial for face representation and recognition. Yu Su *et al*. [100] have proposed a novel face recognition method which exploits both global and local discriminative features. In their method, global features are extracted from the whole face images by keeping the low-frequency coefficients of Fourier transform, which we believe encodes the holistic facial information, such as facial contour. For local feature extraction, Gabor wavelets are exploited considering their biological relevance. After that, Fisher's linear discriminant (FLD) was separately applied to the global Fourier features and each local patch of Gabor features. Thus, multiple FLD classifiers were obtained, each embodying different facial evidences for face recognition. Finally, all those classifiers are combined to form a hierarchical ensemble classifier. They evaluate their proposed method using two large-scale face databases: FERET and FRGC version 2.0. Experiments show that the results of our method are impressively better than the best known results with the same evaluation protocol.

Nicholl *et al*. [101] have introduced a novel methodology that combines the multiresolution feature of the discrete wavelet transform (DWT) with the local interactions of the facial structures expressed through the structural hidden Markov model (SHMM). A range of wavelet filters such as Haar, biorthogonal 9/7, and Coiflet, as well as Gabor, have been implemented in order to search for the best performance. SHMMs perform a thorough probabilistic analysis of any sequential pattern by revealing both its inner and outer structures simultaneously. Unlike traditional HMMs, the SHMMs do not perform the state conditional independence of the visible observation sequence assumption. That was achieved via the concept of local structures introduced by the SHMMs. Therefore, the long-range dependency problem inherent to traditional HMMs has been drastically reduced. SHMMs have not previously been applied to the problem of face identification. The results reported in their application have shown that SHMM outperforms the traditional hidden Markov model with a 73% increase in accuracy.

Guan-Chun Luh and Chun-Yi Lin [102] have described a face recognition method using artificial immune networks based on principal component analysis (PCA). The PCA abstracts principal eigenvectors of the image in order to get best feature description, hence to reduce the number of inputs of immune networks. Henceforth those image data of reduced dimensions were input into immune network classifiers to be trained. Subsequently the antibodies of the immune networks are optimized using genetic algorithms. The performance of their method was evaluated employing the AT&T Laboratories Cambridge database. The results show that their method gains higher recognition rate in contrast with most of the developed methods.

2.4 PALMPRINT RECOGNITION SYSTEMS

Palmprint is promising biometric feature for use in access control and forensic applications. The Palmprint-based personal identification, as a new member in the biometrics family, has become an active research topic in recent years. The rich texture information of palmprint offers one of the powerful means in the field of personal recognition.

Adams Kong *et al*. [103] have proposed a feature-level fusion approach for improving the efficiency of palmprint identification. Multiple elliptical Gabor filters with different orientations were employed to extract the phase information on a palmprint image, which was then merged according to a fusion rule to produce a single feature called the Fusion Code. The similarity of two Fusion Codes was measured by their normalized hamming distance. A dynamic threshold was used for the final decisions. A database containing 9599 palmprint images from 488 different palms was used to validate the performance of the proposed method. Comparing their previous non-fusion approach and their proposed method, improvement in verification and identification were ensured.

De-Shuang Huang *et al*. [104] have proposed a novel palmprint verification approach based on principal lines. In feature extraction stage, the modified finite Radon transform was proposed, which can extract principal lines effectively and efficiently even in the case that the palmprint images contain many long and strong wrinkles. In matching stage, a matching algorithm based on pixel-to-area comparison was devised to calculate the similarity between two palmprints, which has shown good robustness for slight rotations and translations of palmprints. The experimental results for the verification on Hong Kong Polytechnic University Palmprint Database show that the discriminability of principal lines was also strong.

Dewen Hu *et al*. [105] have presented a novel algorithm for image feature extraction, namely, the two-dimensional locality preserving projections (2DLPP), which directly extracts the proper features from image matrices based on locality preserving criterion. Experimental results on the PolyU palmprint database show the effectiveness of the proposed algorithm.

Prasad *et al*. [106] proposed a wavelet-based palmprint verification approach which was efficient in terms of accuracy and speed. The prominent wavelet domain features such as subband energy distribution, histogram, and co-occurrence features fail to characterize the palmprints sufficiently due to coefficient perturbations caused by translational and/or rotational variations in palmprints. In their work, firstly, a novel approach, termed as adaptive tessellation of subbands, was proposed to effectively capture the spatially localized energy distribution based on the spread of principal lines. Secondly, a set of discriminating features, termed as high scale codes (HSCODEs), and a translation and rotation invariant matching technique were proposed. HSCODEs effectively characterize the palmprints by capturing the spatial patterns corresponding to the low frequency components. Energy features and selected HSCODEs were fused at score and decision levels. Particularly, score level fusion enhances the verification accuracy significantly. Effectiveness of their proposed approach was examined on

PolyU-ONLINE-Palmprint-II (PolyU) database. The experimental results show an overall equal error rate (EER) of 0.22%, which was better than the existing wavelet-based palmprint recognition systems and comparable to the computationally complex state-of-the-art approaches. The speed of the approach was high as all the features are extracted from the same wavelet decomposition of palmprint.

Ito *et al*. [107] have proposed a palmprint recognition algorithm using Phase-Only Correlation (POC). The use of phase components in 2D (two-dimensional) discrete Fourier transforms of palmprint images makes it possible to achieve highly robust image registration and matching. In their algorithm, POC was used to align scaling, rotation and translation between two palmprint images, and evaluate similarity between them. Experimental evaluation using a palmprint image database clearly demonstrates efficient matching performance of their proposed algorithm.

Previous research on palmprint recognition mainly concentrates on low resolution (about 100 ppi) palmprints. But for high-security applications (e.g. forensic usage), high resolution palmprints (500 ppi or higher) are required from which more useful information can be extracted. Dai J and Zhou J *et al*. [108] have described a novel recognition algorithm for high-resolution palmprint. The main contributions of the proposed algorithm include: (1) Use of multiple features, namely minutiae, density, orientation and principal lines for palmprint recognition to significantly improve the matching performance of the conventional algorithm. (2) Design of a quality based and adaptive orientation field estimation algorithm, which performs better than the existing algorithm in case of regions with large number of creases. (3) Use of a novel fusion scheme for identification application which performs better than conventional fusion methods, e.g. weighted sum rule, SVMs or Neyman-Pearson rule. Besides, they analyze the discriminative power of different feature combinations and find that density was very useful for palmprint recognition. Experimental results on the database containing 14,576 full palmprints show that the proposed algorithm has achieved a good performance.

Ling Lin [109] has proposed a novel approach for handprint identification. Firstly, region of interest was segmented through hand's key points localization, then PCA algorithm was used to extract the palmprint features. A hierarchical neural network structure was employed to measure the degree of similarity in the identification stage. Experimental results show that the designed system achieves an acceptable level of performance.

The competitive coding scheme, one representative coding-based method, first convolves the palmprint image with a bank of Gabor filters with different orientations and then encodes the dominant orientation into its bitwise representation. Despite the effectiveness of competitive coding, few investigations have been given to study the influence of the number of Gabor filters and the orientation of each Gabor filter. In their paper, based on the statistical orientation distribution and the orientation separation characteristics, Feng Yue *et al*. [110] have presented a modified fuzzy C-means cluster algorithm to determine the orientation of each Gabor filter. Since the statistical orientation distribution was based on a set of real palmprint images, their proposed method was more suitable for palmprint recognition. Experimental results indicate that their proposed method achieves higher verification accuracy while compared with that of the original competitive coding scheme and several state-of-the-art methods, such as ordinal measure and RLOC. Considering both the computational complexity and the verification accuracy, competitive code with six orientations would be the optimal choice for palmprint recognition.

Wangmeng Zuo *et al*. [111] have described the orientation feature which has been demonstrated to be one of the most effective features for low resolution palmprint recognition. In their paper, using steerable filter, they investigate the accurate orientation extraction and appropriate distance measure problems for effective palmprint recognition. First, they use high order steerable filter to extract accurate continuous orientation, and quantify it into discrete representation. Then, for effective matching of accurate orientations, they proposed a generalized orientation distance measure. They further extend the distance measure for matching of discrete orientations, and show that several existing distance measures can be viewed as its special cases. Experimental results on both Hong Kong PolyU and CASIA palmprint databases show that the proposed method can obtain state-of-the-art verification accuracy. With the support of a look up table, their proposed method also enables small template size and satisfactory matching speed for practical applications.

Koichi Ito *et al*. [76] have presented a major approach for palmprint recognition which was to extract feature vectors corresponding to individual palmprint images and to perform palmprint matching based on some distance metrics. One of the difficult problems in feature-based recognition was that the matching performance is significantly influenced by many parameters in feature extraction process, which may vary depending on environmental factors of image acquisition. Their paper presents a palmprint recognition algorithm using phase-based image matching. The use of phase components in 2D (two-dimensional) discrete Fourier transforms of palmprint images makes possible to achieve highly robust palmprint recognition. Experimental evaluation using a palmprint image database clearly demonstrates an efficient matching performance of their algorithm.

2.5 FINGERPRINT RECOGNITION SYSTEMS

Fingerprint verification has emerged as one of the most reliable means of biometric authentication due to its universality, distinctiveness, permanence and accuracy. Contrary to popular belief, inspite of its long history and extensive research efforts, automated fingerprint recognition is not a closed problem. Reliable matching of fingerprints is a challenging problem. Here, we have presented some of the significant researches for finger print recognition.

Malathi and Meena [80] have proposed a new strategy for fingerprint matching based on pores by reliably extracting the pore features The extraction of pores was done by Marker Controlled Watershed segmentation method and the centroids of each pore were considered as feature vectors for matching of two fingerprint images. Experimental results show that their method provides good results leading to faster and improved matching rates.

Ravi *et al*. [81] have presented the popular Biometric Finger print, used to authenticate a person which was unique and permanent throughout a person's life. A minutia matching was widely used for fingerprint recognition and can be classified as ridge ending and ridge bifurcation. In their paper they projected Fingerprint Recognition using Minutia Score Matching method (FRMSM). For Fingerprint thinning, the Block Filter was used, which scans the image at the boundary to preserves the quality of the image and extract the minutiae from the thinned image. The false matching ratio was better compared to the existing algorithm.

Abrishambaf *et al*. [82] have described a fully Cellular Neural Networks (CNN) based fingerprint recognition system. The system includes a preprocessing phase where the input fingerprint image was enhanced and a recognition phase where the enhanced fingerprint image was matched with the fingerprints in the database. Both preprocessing and recognition phases were realized by means of CNN approaches. A novel application of skeletonization method was used to perform ridgeline thinning which improves the quality of the extracted lines for further processing, and hence increases the overall system performance.

Jinwei Gu *et al*. [83] have presented an important feature, orientation field which described the global structure of fingerprints. It provides robust discriminatory information other than traditional widely-used minutiae points. However, there were few works explicitly incorporating this information into fingerprint matching stage, partly due to the difficulty of saving the orientation field in the feature template. In their paper, they proposed a novel representation for fingerprints which includes both minutiae and model-based orientation field. Then, fingerprint matching can be done by combining the decisions of the matchers based on the global structure (orientation field) and the local cue (minutiae). They have conducted a set of experiments on large-scale databases and made thorough comparisons with the state-of-the-arts. Extensive experimental results show that combining those local and global discriminative information can largely improve the performance. Their proposed system was more robust and accurate than conventional minutiae-based methods, and also better than the previous works which implicitly incorporate the orientation information. In their system, the feature template takes less than 420 bytes, and the feature extraction and matching procedures can be done in about 0.30 s. They also show that the global orientation field was beneficial to the alignment of the fingerprints which were either incomplete or poor-qualitied.

Heeseung Choi *et al*. [84] have introduced a novel fingerprint matching algorithm using both ridge features and the conventional minutiae feature to increase the recognition performance against nonlinear deformation in fingerprints. Their proposed ridge features were composed of four elements: ridge count, ridge length, ridge curvature direction, and ridge type. Those ridge features have some advantages in that they can represent the topology information in entire ridge patterns existing between two minutiae and are not changed by nonlinear deformation of the finger. For extracting ridge features, they also define the ridge-based coordinate system in a skeletonized image. With the proposed ridge features and conventional minutiae features (minutiae type, orientation, and position), they proposed a novel matching scheme using a breadth-first search to detect the matched minutiae pairs incrementally. Following that, the maximum score was computed and used as the final matching score of two fingerprints. Experiments were conducted for the FVC2002 and FVC2004 databases to compare the proposed method with the conventional minutiae-based method. The proposed method achieved higher matching scores. Thus, they concluded that the proposed ridge feature gives additional information for fingerprint matching with little increment in template size and can be used in conjunction with existing minutiae features to increase the accuracy and robustness of fingerprint recognition systems.

Ching-Liang Su [85] has described that the "vector magnitude invariant transform" technique which was used to transfer the ring-circle-signal quantities to an invariant vector magnitude quantity. By the invariant vector magnitude quantity, one can perform the object-identification. The "vector magnitude invariant transform" technique can solve the image rotation problem. In his study, several vector magnitude quantities were combined to one quantity and this combined quantity is saved inside one specific pixel. By his approach, one pixel will possess more fingerprint geometry-features. The comparison approaching in their study was by the basis of one-pixel-to-one-pixel-comparison and by his scheme one can find the maximum matching points of two objects. In his study, one hundred and five comparisons are conducted to find the accuracy-rate of the developed algorithm. Within those 105 comparisons, 15 comparisons were conducted for self-comparison. The other 90 comparisons were conducted for comparisons between two different object images. The algorithm developed in his study can precisely classify the object image.

Alessandra Lumini and Loris Nanni [86] have presented a new method for minutiae-based fingerprint verification that approaches the problem as a two-class pattern recognition problem. In their knowledge, that was one of the first works that uses as features for fingerprint verification the response of a minutiae matcher between two fingerprints. The feature vector obtained by the minutiae matching was classified into "genuine" or "impostor" by support vector machines. Results from FVC2002 were presented, yielding remarkable performance improvement with respect to other state-of-the-art approaches.

Chia-Hung Lin *et al*. [87] have proposed that biometric-based fractal pattern classifier for fingerprint recognition using grey relational analysis (GRA). Fingerprint patterns have arch, loop, whorl, and accidental morphology, and embed singular points, which result in establishing fingerprint individuality. An automatic fingerprint identification system consists of three stages: image acquisition and processing, feature extraction, and pattern recognition. Fingerprint images were captured from subjects using an optical fingerprint reader (OFR). Digital image preprocessing (DIP) was used to refine out noise, enhance the image, convert to binary image, and locate the reference point. For binary images, Katz's algorithm was employed to estimate the fractal dimension (FD) from two-dimension (2D) image. Biometric characteristics were extracted as fractal patterns using Weierstrass cosine function (WCF) with different FDs. GRA performs to compare the fractal patterns among the small-scale database.

Hashad *et al*. [88] have presented a new fingerprint recognition method based on mel-frequency cepstral coefficients (MFCCs). In their method, cepstral features were extracted from a group of fingerprint images, which were transformed first to 1-D signals by lexicographic ordering. MFCCs and polynomial shape coefficients were extracted from these 1-D signals or their transforms to generate a database of features, which can be used to train a neural network. The fingerprint recognition can be performed by extracting features from any new fingerprint image with the same method used in the training phase. These features were tested with the neural network. The different domains were tested and compared for efficient feature extraction from the lexicographically ordered 1-D signals. Experimental results show the success of the proposed cepstral method for fingerprint recognition at low as well as high signal to noise ratios (SNRs). Results also show that the discrete cosine transform (DCT) was the most appropriate domain for feature extraction.

Andreas Uhl and Peter Wild [89] have described that the multiple instances of single biometrics can be acquired from a single input simultaneously, a multiple-step acquisition at additional transaction time cost can be avoided. They presented a rotation-invariant, peg-free multi-instance fingerprint and eigen finger-based biometric system extracting multiple features from a palmar scan of the hand. Their evaluation targets: (1) rankings of individual fingers with respect to minutiae and eigen finger features; (2) fusion of multi-instance intra-feature (minutiae or eigen finger) matching scores; (3) cross-feature compared to intra-feature performance; (4) optimal weights for weighted versions of five score-level fusion methods such as max, median, min, product and sum and (5) aspects of computational demands for hand-based identification discussing the usage of serial classifier combinations instead of classically employed parallel ones. They examine results of an experimental approach to the problem of finding a suitable fusion method by investigating the effect of matcher-specific combination weights on recognition accuracy and compare cross-feature and intra-feature score combinations.

Haiyun Xu *et al*. [90] have described the spectral minutiae representation which was a method to represent a minutiae set as a fixed-length feature vector, which was invariant to translation, and in which rotation and scaling become translations, so that they can be easily compensated for. These characteristics enable the combination of fingerprint recognition systems with template protection schemes that require as an input a fixed-length feature vector. Based on the spectral minutiae features, their paper introduces two feature reduction algorithms: the Column Principal Component Analysis and the Line Discrete Fourier Transform feature reductions, which can efficiently compress the template size with a reduction rate of 94%. With reduced features, they can also achieve a fast minutiae-based matching algorithm. Their paper presented the performance of the spectral minutiae fingerprint recognition system and shows a matching speed with 125 000 comparisons per second on a PC with Intel Pentium D processor 2.80 GHz and 1 GB of RAM. Their fast operation renders our system suitable as a pre selector for a large-scale fingerprint identification system, thus significantly reducing the time to perform matching, especially in systems operating at geographical level (e.g., police patrolling) or in complex critical environments (e.g., airports).

Linlin Shen and Alex Kot [91] have presented a new fingerprint recognition approach based on features extracted from the wavelet domain. The 64-subband structure proposed by the FBI WSQ standard was used to decompose the frequency of the image. The efficiency of the method was achieved by using the k-nearest neighbor (k-NN) classifier. The result was compared with other image-based methods. For compressed fingerprint images, their proposed method can achieve much lower computational efforts.

V. N. Perminov and A. M. Fartukov [92] have presented a method for fingerprint matching, which was based on the use of additional information about the representation of fingerprint minutiae. However, in contrast with the prototype, their method uses both the characteristic of local regions of the directional field and the local configurations of minutiae present in the fingerprint.

S. Tachaphetpiboont *et al.* [59] proposed a feature extraction method based on the fast Fourier transform (FFT) for the use of fingerprint matching. The performance of their approach was evaluated by the amount of time required in the features extracting and feature matching processes. The recognition rate obtained from the proposed method was also evaluated by the k-NN classifier.

Chebira *et al* [60] have proposed an adaptive multiresolution (MR) approach to the classification of fingerprint images. Their system adds MR decomposition in front of a generic classifier consisting of feature computation and classification in each MR subspace, yielding local decisions, which was combined into a global decision using a weighting algorithm. In their work on classification of protein subcellular location images, they showed that the space-frequency localized information in the MR subspaces adds significantly to the discriminative power of the system. They developed a new weighting method which allows for the discriminative power of each subband to be expressed and examined within each class. That allows us to evaluate the importance of the information contained within a specific subband. Moreover, they develop a pruning procedure to eliminate the subbands that do not contain useful information. That leads to potential identification of the appropriate MR decomposition both on a per class basis and for a given dataset. With their new approach, they make the system adaptive, flexible as well as more accurate and efficient.

2.6 TOUCHLESS FINGERPRINT RECOGNITION SYSTEMS

Touchless fingerprint recognition is considered as a feasible alternative to touch-based fingerprint recognition technology. Touchless fingerprint technology provides a near perfect solution to the problems in terms of hygienic, maintenance and latent fingerprints.

Hiew *et al.* [74] have proposed the Touch-less fingerprint recognition which was regarded as a viable alternative to contact-based fingerprint recognition technology. It provides a near ideal solution to the problems in terms of hygienic, maintenance and latent fingerprints. In their paper, they presented a touch-less fingerprint recognition system by using a digital camera. Specifically, they address the constraints of the fingerprint images that were acquired with digital camera, such as the low contrast between the ridges and the valleys in fingerprint images, defocus and motion blurriness.

The system comprises of preprocessing, feature extraction and matching stages. Their proposed preprocessing stage shows the promising results in terms of segmentation, enhancement and core point detection. Feature extraction was done by Gabor filter and the favorable verification results were attained with the support vector machine.

Yeegahng Song *et al*. [75] have proposed that the Fingerprint-based recognition systems were widely used in the field of biometrics. Most of the fingerprint sensors developed so far acquire fingerprint images through the surface of a solid plate, which degrades the recognition performance due to deformations. Those deformations are caused by the pressure of the physical contact that was costly and hard to estimate. A touchless fingerprint recognition system was devised using a camera sensor to resolve this problem. However, this system raises some new problems, such as defocusing, low ridge-valley contrast, 3D-to-2D mapping, and so forth. Adequate solutions were discussed by introducing modified steps to the algorithm. Their proposed system was compared with a primitive touchless sensor with no manipulation and the algorithm of the preceding touch-based system.

Geppy Parziale [77] has described that fingerprint image acquisition was the most critical step of an automated fingerprint authentication system, as it determines the final fingerprint image quality, which has drastic effects on the overall system performance. When a finger touches or rolls onto a surface, the elastic skin deforms. The quantity and direction of the pressure applied by the user, the skin conditions, and the projection of an irregular 3D object (the finger) onto a 2D flat plane introduce distortions, noise, and inconsistencies on the captured fingerprint image. These problems have been indicated as inconsistent, irreproducible, and non-uniform contacts and, during each acquisition, their effect on the same fingerprint is different and uncontrollable. Hence, the representation of the same fingerprint changes every time the finger was placed on the sensor platen, increasing the complexity of fingerprint matching and representing a negative influence on system performance with a consequent limited spread of their biometric technology. Their approach, referred to as touch less or contactless fingerprinting, tries to overcome the above-cited problems. Because of the lack of contact between the finger and any rigid surface, the skin does not deform during the capture and the repeatability of the measure was ensured.

A fingerprint capture consists of touching or rolling a finger onto a rigid sensing surface as described by Parziale *et al*. [78]. During their act, the elastic skin of the finger deforms. The quantity and direction of the pressure applied by the user, the skin conditions, and the projection of an irregular 3D object (the finger) onto a 2D flat plane introduce distortions, noise, and inconsistencies on the captured fingerprint image. Due to these negative effects, the representation of the same fingerprint changes every time the finger was placed on the sensor platen, increasing the complexity of the fingerprint matching and representing a negative influence on the system performance. Recently, a new approach to capture fingerprints has been proposed. Their approach, referred to as touch less or contactless fingerprinting, tries to overcome the above-cited problems. Because of the lack of contact between the finger and any rigid surface, the skin does not deform during the capture and the repeatability of the measure is quiet ensured. However, their technology introduces new challenges. Finger positioning, illumination, image contrast adjustment, data format compatibility, and user convenience were key in the design and development of touch less fingerprint systems. In addition, vulnerability to spoofing attacks of some touch less fingerprint systems must be addressed.

Pooja Gautam [79] has presented that touch-less fingerprint recognition was as a feasible alternative to touch-based fingerprint recognition technology. Touch-less fingerprint technology provides a near perfect solution to the problems in terms of hygienic, maintenance and latent fingerprints. Their paper presents an introduction to touch-less fingerprint recognition system using a digital camera. Their paper also discusses both the disadvantages and the advantages of touch-less fingerprint systems along with the approaches to capture touch-less fingerprint.

CHAPTER 3

MULTIBIOMETRIC HUMAN RECOGNITION SYSTEM