CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE SURVEY ON MULTIMODAL BIOMETRICS

A multimodal sparse representation method representing test data by a sparse training data linear combination constraining observations from varied test subject modalities to share sparse representations was proposed by Shekhar et al., (2014). Simultaneously, correlations and coupling information among biometric modalities was also considered. A multimodal quality measure to weigh each modality as it was fused was proposed. Further, the algorithm was kernalized to handle data nonlinearity. Optimization issues were solved using an alternative direction method. Experiments showed that the new method compared favourably with current fusion-based methods.

A new evolutionary approach to adaptive, multiple biometrics combination to ensure optimal performance for desired security levels was presented by Kumar et al., (2010) and determined optimal fusion strategy and corresponding fusion parameters. Score-level fusion rules ensured desired system performance using a hybrid Particle Swarm Optimization (PSO) model. Results proved that the new score-level approach achieved better performance over decision-level approaches. There was little effort in literature to investigate an adaptive multimodal fusion algorithm’s performance on real biometric data. It also presented the proposed approach’s performance from real biometric samples to validate contributions.
Merits of using multimodal structures was evaluated by Abreu et al., (2009) who also, investigated how different strategies for implementation increased degree of choice in achieving specific performance criteria. Implementation merits were based on multi-agent computational architecture to achieve high performance levels when recognition accuracy was a criterion. It also revealed this strategy’s relative merits compared to commonly adopted approaches to practical system realization. A new approach was proposed to implement a negotiating agents based multimodal system.

Multimodal fusion issues involving missing modalities (scores) using Support Vector Machines (SVMs) with Neutral Point Substitution (NPS) method was addressed by Poh et al., (2010). It started by processing every modality with a kernel. When a modality was missing, at kernel level, it was substituted by an unbiased one regarding classification, called neutral point. Explicit calculation of neutral points unlike conventional missing-data substitution methods could be omitted due to incorporation in SVM training framework. Experiments on Biosecure DS2 multimodal (scores) data set revealed that SVM-NPS approach achieved very good generalization compared to sum rule fusion, specially with severe missing modalities.

A new, video-based multimodal biometric verification scheme using low-level feature fusion of speech and face developed for speaker recognition for perceptual Human-Computer Interaction (HCI) by Jiang et al., (2010) where human face was tracked and face pose estimated to weight detected face like regions in frames, where ill-posed faces and false-positive detections were assigned with lower credit to improve accuracy. Mel-frequency cepstral coefficients were extracted for voice-based biometric verification in audio modality. Infusion, both modality features were projected into nonlinear Laplacian Eigen map subspace for multimodal
speaker recognition being combined at a low level. The new approach was tested on a ten human subject video database with results showing that the new scheme attained improved accuracy compared to traditional multimodal fusion using latent semantic analysis and single-modality verifications. MATLAB experiments revealed the new scheme’s potential in attaining real-time performance for perceptual HCI applications.

Two sub-problems, depending whether device identity was known or unknown was distinguished by Poh et al., (2010). In a fusion context, after normalizing every device output independently, outputs were combined using Naive Bayes principal. They compared many state-of-the-art quality-based score normalization procedures, based on whether a relationship between quality measures and score was modeled, as follows: 1) direct modeling; 2) modeling via quality measures cluster index; and 3) extending to further include device information (device-specific cluster index). Experiments on Biosecure DS2 data set proved that the last approach reduced false acceptance and false rejection rates simultaneously. Further, the compounded effect of normalizing every system individually in multimodal fusion improved performance over baseline fusion (without quality information) when device information was given.

An innovative, iris and fingerprint traits based multimodal biometric identification system was proposed by Conti et al., (2010). A frequency-based approach in detail, leads to a homogeneous biometric vector, which integrates iris and fingerprint data. A hamming-distance-based matching algorithm deals with unified homogenous biometric vector. The new multimodal system achieved results with many common databases. A working point with FAR = 0% and FRR = 5.71% using entire Fingerprint Verification Competition (FVC) 2002 DB2B database extracted same-size subset of BATH database. Simultaneously, considering BATH database and
A new multimodal biometric approach integrating finger vein recognition and finger geometry recognition at score level was proposed by Kang and Park (2010). It had 3 advantages compared to earlier works: (i) the new multimodal biometric system constructed as a tiny device, used a finger vein and finger geometry features from one finger; (ii) the new finger geometry recognition, based on Fourier descriptors, is robust to a finger’s translation/rotation; and (iii) authors got better recognition accuracy using SVM based score-level fusion than by other score-level fusion methods like MAX, MIN and SUM rules. Results revealed that equal error rate of new method decreased by as much as 1.089 and 1.627% compared to finger vein recognition and finger geometry recognition methods, respectively.

A new, Complex Common Vector (CCV) based multimodal biometric recognition algorithm was proposed by Wang et al., (2009). CCV generalises common vector method for complex fields to perform feature fusion and classification. Theoretical analysis revealed that CCV produced a unique common vector for each fusion feature in given class. Iris and face were used as two distinct biometric modals to test algorithm. Results showed that the new algorithm achieved better performance than conventional multimodal biometric algorithms.

A fusion scheme combining information from several domain experts and based on rank-level fusion integration method was presented by Monwar and Gavrilova (2009). The developed multimodal biometric system had many unique qualities, from utilizing Fisher's linear discriminant and PCA methods for individual matchers (face, ear, and signature) to identity authentication and utilizing novel rank-level fusion method to consolidate results from various biometric matchers. Individual matcher’s ranks were
combined using highest rank, Borda count, and logistic regression approaches. Results indicated that individual modalities fusion improved overall biometric system performance, even in low quality data. Insights on multi-biometric design using rank-level fusion and performance on various biometric databases was discussed in the concluding section.

A biometric system for identification based on three biometric hand characteristics including palm print, finger surfaces and hand geometry was proposed by Ramalho et al., (2012). A protection scheme was applied to biometric template data to guarantee security, revocability and diversity among biometric systems. A Cryptographic Hash Function (CHF), an Error-Correcting Code (ECC), and a binarisation module were the template protection scheme core. As ECC and CHF operate on binary data, an additional feature binarisation step was needed. This was proposed: (i) a novel identification architecture using hand geometry as soft biometric to accelerate identification process and ensure system scalability; and (ii) a new, feature binarisation technique guaranteeing that Hamming distance between transformed binary features was same as difference between real values. The new system achieved good recognition and speed performances on two hand image databases.

Yang (2010) proposed biometrics verification techniques combining digital signature for multimodal biometrics payment systems. Considering fingerprint and face’s distinctiveness, universality and easy collectability, a multimodal biometrics verification system is designed, and hybrid fingerprint features and InfraRed(IR) face features for matching was meant to overcome traditional methods shortcomings and ensure registered multimodal biometrics data integrity. Nine authentication models to authenticate an open network to ensure data integrity was analyzed. Finally, a digital signature procedure with Public Key Infrastructure (PKI) to prove a
multimodal biometrics payment system safely was proposed. The new system was applicable to public key platforms too.

A multimodal biometrics system combining fingerprint and palm print features to overcome unimodal biometrics limitations was proposed by Mhaske and Patankar (2013). The resulting images were combined in feature level fusion and through use of Euclidean distance features were classified to match resultant image with database template. The new methodology had improved performance compared to unimodal approaches using only a fingerprint or a palm print individually. Multiple biometrics reduced system error rate.

A multimodal biometric prototype that captured a palm vein and 3 fingerprints simultaneously and evaluated whether this combination was statistically independent was proposed by Yamada et al., (2012). Evaluating false acceptance using palm vein images and fingerprint images with prototype, confirmed that palm vein and fingerprints combination was almost independent.

A multimodal biometrics system on faculty of organisational sciences using open source technology was developed by Milenkovic et al., (2011). Unimodal biometric solutions were presented, system performance measurements for various information fusion methods given and multimodal biometric database used to test system performance was described.

Hand vein biometric in unimodal status was analyzed by Raghavendra et al., (2010) along with palm print in multimodal scenario. A key aspect was extracting hand vein features. Using non-standard edge mask in schemes to extract hand vein pattern accurately was also proposed. This, in turn was classified with Kernel Direct Discriminant Analysis (KDDA) to make acceptance/rejection decisions. The new non-standard edge masks
performance was compared to conventional edge detection masks and results statistical validation was presented with a 90% confidence interval. The scheme’s robustness was analyzed by evaluating the algorithms and schemes on noise corrupted data. Final results proved the scheme’s efficacy.

An improved, correlation analysis based, reversible data hiding approach for multimodal biometric identification to ensure multimodal biometric images security and integrity was proposed by Jiangyan Dai et al., (2011). Considering biometrics characteristics, correlation analysis was first used between face image and palm image to enhance security. A residual image was got by exploiting spatial and content correlation. Then an improved method to embed residual palm image into face image for secure transmission was presented. Finally, image authentication for more multimodal biometric identification at receiver was performed. Once images were true, identification for further identity authentication was undertaken. Experiments demonstrated that the new method had better quality than earlier work and perfect security was validated on biometric identification.

Extracting a feature set from data, and comparing the set with the database template was proposed by Gudavalli et al., (2012). Multimodal biometric systems used more than one physiological or behavioural characteristic for verification, enrolment or identification. Studies proved that multimodal biometric systems had improved performance compared to Unimodal systems. Here, various multimodal sources, multimodal architectures and various fusion techniques used in multimodal biometric systems are discussed.

Elbio, a platform to facilitate multimodal biometrics learning through tutorial-like system interaction was presented by Sosevic et al., (2012). This guides potential biometric trainees through various steps common for most multimodal biometric system development. Trainees
assemble a sample system proceeding through defined phases. Simultaneously, learning and acquiring practical knowledge happened quicker compared to traditional book-style learning.

Multimodal biometrics for face and palmprint images with fusion techniques at feature level was introduced by Ahmad et al., (2010). Gabor based image processing extracted discriminant features, while PCA and Linear Discriminant Analysis (LDA) reduced each modality’s dimension. LDA output features were serially combined and classified by Euclidean distance classifier. ORL face and Poly-U palmprint databases based results proved that this technique increased biometric recognition rates compared to that of single modal biometrics.

2.2 LITERATURE SURVEY ON MULTIMODAL BIOMETRICS USING SOFT COMPUTING TECHNIQUES

Saropourian (2009) proposed the exact opposite of finger-print recognition’s classic patterns as they worked on single dots on finger-print liked ridge-ending and bifurcation. This observation was about finger-print recognition using single streak state in finger-print image, as veins patterns in finger-print could be used for identifying a person. This algorithm works on binary images and on gray scanned photos.

Experimental data from an eye tracker was analyzed by Shapoori and Allinson (2011) by clustering analysis and a NN based system to learn experts search strategy. Eye tracking technology recorded eye movement and provided information about user search strategy. Results revealed that the system predicted expert's experience based optimum search strategy.

A touch-less finger print system whose hardware was limited to a webcam and processor was proposed by Ravi and Sivanath (2013). Current
biometric systems are costly or unhygienic, and a healthy person could acquire a disease from system used by a diseased person. For many reasons, users are reluctant to touch biometric scanners. Even here, fingerprint is a person’s most unique feature. Webcams are associated with today's laptops making it easier to implement the system. The proposal was basically a software capable of being implemented anywhere with a PC and webcam. A web camera captured the user's finger for recognition, at a distance and this was isolated from the background and ridges extracted. The finger print was processed in Euclidean space to get minutiae points. Spurious minutiae were removed and minutiae point’s orientations and Euclidean distances were saved for future matching. The system is applicable to all fields ‘specially personal security (PC, Laptops and Mobile Phones), defence, attendance and ATMs.

A multi-biometric based authentication system with GUI interface discussed by Vijayalakshmi et al., (2013) includes an extraction algorithm for feature extraction from given finger print and a palm print feature extraction algorithm to extract these features. Then both algorithms are integrated to perform multi-biometric authentication. Unimodal biometric systems contend with various issues like intra-class variations, noisy data, non-universality, restricted freedom, spoof attacks and unacceptable error rates. Some limitations are addressed by using multimodal biometric systems which combine evidence from multiple information sources. The new fingerprint and palm print algorithm proved to consume less computation time and occupy less memory space compared to current algorithms. Fingerprint and palm print matching results for the new method was validated and system integrity in all cases evaluated.

A quicker and efficient way to remove salt-and-pepper impulse noise and edge-preserving regularization of obtained finger print noise free
image using B-Splines was suggested by Jayasree and Kumar (2013). Accuracy of a biometric identification and authentication systems in image forensics depends on image quality to reach reliable results. To ensure noise-free fingerprint image, they are subjected to pre-processing and filtering. Results were much better than earlier proposed nonlinear filters or regularization methods regarding noise removal as also image forensics edge regularization.

A new method for secured exchange between an E-passport or E-driving license and Inspection System is proposed by Nathan et al., (2011). The aim of the new method was creation of elliptic curve points from fingerprint using MATLAB. Minutiae from fingerprints were extracted first and then an elliptic curve was generated using elliptic curve cryptography generation algorithm. Many countries issue E-driving license and E-passports with biometric data for their people. ICAO E-passport specification for cryptography proved insecure and had threats. The European Union uses EAC for E-passports. But this also has issues as regards threats especially in security and privacy. Biometric template recognition was challenging in real world applications. Thus, biometric data based elliptic curve to validate user identity was created and confirmed that the solution corresponded to security goals defined.

Technical details and performance comparison of available fingerprint sensors were emphasized by Ashwini et al., (2010) who also explored future direction and system development that use such techniques for Chance fingerprint enrolment. The study indicated that poor calibration error had greater impact on generated overall system output and related to serious usability issues on handling fingerprint sensors. Various fingerprint enrolment sensors comparison table revealed that Radio Frequency, Optical,
Multi Spectrum Imaging, Micro-X-ray Fluorescence Elemental Imaging sensor techniques ensured highest accuracy and compatibility.

A knuckle SURF algorithm based print recognition algorithm was proposed by Zhu Le-qing (2011). First, a coordinate system was defined based on local convex direction Finger Knuckle Print (FKP) map to align images and a Region Of Interest (ROI) cropped for feature extraction; secondly, key points were extracted with fast Hessian detector, to which an orientation was assigned according to Haar wavelet responses inside neighbor key point circle area; an orientation invariant descriptor was constructed for every key point. In recognition, testing FKP features was matched to template features for initial correspondences, and then RANdom SAmple Consensus (RANSAC) established geometric constraint to remove false matching. Final matched point pairs were referred to, to decide two palm images constituency. Experiments show that FKP was recognized with high accuracy. The method was rotation, scale and viewpoint changes invariant proving its robustness.

A smooth l0 norm spare representation model based FKP algorithm was proposed by Zhai et al., (2012). First, an over-complete dictionary was constructed using training samples, followed by Local Binary Pattern (LBP) operator for feature extraction and dimension reduction. Finally, smooth l0 norm solved the model, accelerated recognition and improved efficiency. Results on FKP database of the Hong Kong Polytechnic University revealed that the new method achieved competitive results with state-of-the-art and had much potential for practical applications.

A new approach for ROI segmentation of a finger-knuckle-print using gradient field orientation and local field strength was presented by Kekre and Bharadi (2010). Finger-knuckle-print is an emerging biometric trait. ROI is the area where maximum information is centred; for finger knuckle it was the location surrounding knuckle region. A good system needs
ROI as input for feature vector extraction. The approach was fast and ensured good results in shift in finger-knuckle-placement (translational shift).

A multimodal biometric system for recognition using hand images and integrating two different modalities palmprint and Finger-Knuckle-Print (FKP) was proposed by Meraoumia et al., (2011) which addressed issues of efficient matching algorithm based on Phase-Correlation Function (PCF) and with two biometric modalities, palmprint and the FKP. The 2 modalities were combined and fusion applied at matching-score level. Experiments revealed that the system achieved excellent recognition rate and ensured security than unimodal biometric-based systems.

Zhai and Hu (2011) suggested finger shape and palm print based multi-biometric identification technology based on singular creature features. It uses feature collection methods for various areas and designs a hierarchical matcher from coarse to fine ensuring that a multi-biometric identification system with high recognition accuracy and good extendibility was realized. Results proved that this multi-biometric identification technology greatly increased identifying efficiency and ensured identification security accuracy.

FP and FKP were integrated to construct a matching score level and image level fusion based, efficient multi-biometric recognition system as proposed by Meraoumia et al., (2012). Minimum Average Correlation Energy (MACE) was used and Unconstrained MACE (UMACE) filters with 2 correlation plane performance measures - max peak value and peak-to-side lobe ratio - determined the method’s effectiveness. Results showed that system achieved excellent recognition rate on Hong Kong Polytechnic University (PolyU) FKP and high resolution fingerprint database.

An evaluation which was an open issue in research proposed by Belguechi et al., (2011) aimed to define evaluation methodology for specific
biometric systems by proposing metrics to test their robustness. Secondly, they showed through a cancellable biometric system using finger-knuckle-prints how some privacy properties were checked by attack simulation.

A new biometric identifier, called Finger-Knuckle-Print (FKP) for personal identity authentication was proposed by Zhang et al., (2009). A data acquisition device captured FKP images, and then a FKP recognition algorithm processed acquired data. The extracted FKP image’s local convex direction map was foundation for a coordinate system to align images and a ROI was cropped for feature extraction. A competitive coding scheme, using 2D Gabor filters to extract image local orientation information extracted FKP features. When matching, angular distance measured similarity between two competitive code maps. An established FKP database examined performance of the new system, and results proved this new biometric characteristic’s efficiency.

Attempts were made to improve personal identification accuracy when one sample was registered as template by integrating palmprint and finger-knuckle-print by Shen et al., (2010). To ensure easy fusion, same feature, fusion code, and decision level fusion strategy were used. Results showed improved performance compared to single modal biometrics.

An investigation as to how finger-skin expansion caused by wrinkling impacted scanned finger prints quality and characterized qualitative changes affecting recognition was presented by Krishnasamy et al., (2011). Wet and Wrinkled Finger (WWF) database made available to other researchers was introduced. Of the database’s 300 fingers, 185 were visibly wrinkled after immersion; multiple dry and immersed fingerprints images were acquired. WWF Baseline recognition rates using two algorithms presented a commercial fingerprint recognition algorithm and publicly available Bozorth3 matcher. Specifically accuracy degraded in both
algorithms when Dryfinger to Dry finger verification was compared with Dryfinger to Wet-finger verification. To analyze performance on per-finger basis and note accuracy differences amongst fingers, and to recommend what fingers to use in environments where fingers are likely to be wet. Additionally, it proposed a classifier implementation that decided if incoming query was wrinkled.

Biometrics information was fused in two different aspects by Shariatmadar and Faez (2011) to investigate it in single modality, Finger-Knuckle-Print (FKP) biometric was used. For fusing each FKP information, two different representations of every image were used (Gray-Level intensity and Gabor transform). Fusing information at various levels improves recognition rates significantly. For example, combining information gets 96.56% and 95.4% at feature and matching score levels, respectively. Poly-U Finger-Knuckle-Print database examined performance of the new method and results prove its efficiency.

A new, fusion of finger vein and fingerprint recognition based mobile multimodal biometric system was proposed by Lee et al., (2009). Recognition was completed in a short time as the new system obtains finger vein and fingerprint images simultaneously. Also the new system has processing power and storage for many biometric data using conventional Ultra-Mobile Personal Computer (UMPC) as embedded system.

A fingerprint classification and recognition system which extracts and matches minutiae from input image was proposed by Umamaheswari et al., (2007). The new method includes different stages like image enhancement, line detector based feature extraction, and neural network classification using Back propagation networks and Learning vector quantization. The new system was trained and tested on a Fingerprint Database from university of Bologna Italy, which had 900 samples. The exact
image was recognized from classified database rather than from original set using Crisp K-nearest neighbour algorithm that increased recognition accuracy and reduced time.

An analysis of image quality, minutiae count, and fingerprint images overall performance based on Henry system of fingerprint classification and finger's relative location on presenting hand was presented by Young and Elliott (2007). For this, 50 users submitted 3 images from 4 fingers (index, middle, ring, and little). The national institute of standards and technology, Fingerprint Image Software, analyzed image quality and minutiae count. Neurotechnologija Ltd.'s VeriFinger produced Receiver Operating Characteristics (ROCs) to analyze performance. Results revealed differences in image quality and minutiae count and also in matching performance based on Henry system classification and finger location.

A fingerprint enhancement approach based on "directional filter banks" was proposed by Khan et al., (2003). Directional image could be an image transform, where every image pixel represents local gray level direction’s uniformity. Statistics from directional image segmented the original image. The method suited simple images like fingerprints and images that had only a background and foreground. Fingerprint images were decomposed into 8 directional images and cleaned. Once the 8 directional images were cleaned, final enhanced image was got combining cleaned directional images.

A classification system for arthritic finger joints imaging method was described by Schwaighofe et al., (2003) which was based on a laser imaging technique sensitive to finger joint tissue optical characteristics. From laser images acquired at baseline and follow-up, finger joints were automatically classified as to whether inflammatory status improved or worsened. To perform classification, various linear and kernel-based systems
were implemented and performances compared. Based on results it was felt that laser-based imaging allowed reliable pathological finger joints classification, making it a sensitive for arthritic changes detection.

A system got through decision level fusion of two known biometric sensors to identify a person i.e. Fingerprint sensor and Voice sensor were proposed by Vasuhi et al., (2010). More than one sensor was needed for critical or highly secured areas. A sensor data fusion methodology using Fuzzy Logic approach was suggested. As the new scheme uses cross correlation of field orientation images for fingerprint identification, result ensured good recognition rate. Also, voice recognition systems were speaker-dependent and so a speaker recognition system involving feature extraction and classification systems was designed. Mel-Frequency Cepstral Coefficient (MFCC) extracted features from raw speech signals. The closest match identity was treated as corresponding identity for test speaker. The integrated system overcomes drawbacks of individual sensors. It was tested on MIT-AU database and results revealed improved accuracy.

Two methods using ear and FK images proposed by Tharwat et al., (2012) was based on fusion of images of ear and FK before feature level, ensuring no information loss. It proposed a multi-level fusion method at image and classification levels. Features were extracted from fused images using various classifiers and combined with classifiers outputs in abstract, rank, and fusion score levels. Results showed that the new authentication methods increased recognition rates compared to state-of-the-art methods.

Two new algorithms were proposed by Milshtein et al., (2008). The first, called the Spaced Frequency Transformation Algorithm (SFTA), was based on taking images of fast Fourier transform. The second called Line Scan Algorithm (LSA) compared partial fingerprints and reduced time to
compare full fingerprints. Combining SFTA and LSA provided an efficient recognition technique.

An approach to improve finger-vein identification systems performance was suggested by Kumar and Zhou (2012). It simultaneously acquired finger-vein and low-resolution fingerprint images and combined the two using a new score-level combination strategy. It examined earlier proposed finger-vein identification approaches and developed a new approach proving its superiority over earlier efforts. The use of low-resolution fingerprint images from a webcam was examined to ascertain matching performance from images. Two new score-level combinations, i.e., holistic and nonlinear fusion were developed, investigated and evaluated with popular score-level fusion approaches to ascertain the new system’s effectiveness. Rigorous results on a database of 6264 images from 156 subjects showed significant improvement in performance, i.e., from authentication/recognition experiments.

Yang and Yang (2009) proposed a method using multi-channel Gabor filters for finger-vein enhancement. First, multi-channel Gabor filters were used to protrude vein vessel information with variances in orientations and widths in images. The vein information in diverse scales and orientations of Gabor filters was then combined together to produce an enhanced finger-vein image. Experimental results showed that the proposed method was capable of enhancing finger-vein images effectively and reliably.

An approach, incorporating directional decomposition and Frangi filtering to enhance finger veins was proposed by Yang and Yan (2010). Background subtraction was first processed to improve image contrast and eliminate uneven illumination. Then, vein information as image’s ridge-like directional characters was detected by directional filter bank and enhanced through Frangi filtering after noise removal. Finally, enhanced images were
got from enhanced directional images using finer reconstruction rule. Results showed that the new approach was more effective and robust in enhancing finger-vein images.

A new multimodal biometric recognition of touched fingerprint and finger-vein was proposed by Park et al., (2011). Results confirmed the new method’s efficiency and usefulness.

A review of finger vein authentication device using blood vessel patterns as personal identifying factor was presented by Ibrahim et al., (2012). Vein information is tough to duplicate as veins are internal to human body. Finger vein is extracted from patterns present inside skin so authentication compared to finger, face biometric technology was high. The two important methods used to acquire image from finger vein are contact and non-contact methods. Authentication rate of finger vein technology was similar to that of iris but the disadvantage of iris was application of light directly to eyes. So, among the biometric techniques, finger vein technology encouraged researchers to develop further applications.

A way to optimize finger-vein detection using Genetic Algorithms (GA) to fine-tune image processing parameters in finger-vein biometric FPGA-based system-on-chip embedded system was presented by Khalil-Hani et al., (2012). Tuneable parameters included threshold levels and filtering parameters. Results showed that optimization could reduce EER from 1.004% to 0.101% on same biometric system, negating need for expert system designer intuition on image processing parameters.

A new, low quality vein image based finger vein pattern extraction method generated by common CCD camera by absorbing near-infrared light was proposed by Xiang Yu et al., (2009). First, a local threshold method was adopted to ensure probability set initial points; second, a modified line
tracking algorithm was performed and new probability map obtained; Later, a thorough probability map and a corresponding gray map reflecting vein point probability was synthesized. Finally, a directional neighbourhood analysis was made on previous probability map to extract vein pattern. Results proved that the new method achieved better results than current methods.

An identification using finger vein Location and Direction Coding (LDC) was proposed by Yang et al., (2011). Further, finger vein LDC proposed created a structured feature image for every finger vein. Finally, structured feature image was used to conduct personal identification on finger vein image database, which included 440 vein images from 220 different fingers. The proposed method’s equal error rate for this database was 0.44%.

A pixel-level based fusion method using improved regional energy fusion strategy to implement multispectral finger-vein fusion was proposed by Yang and Jia (2012). The new fusion method took regional energy in a 3*3 sliding window as fusion intensity, and to handle redundant information in some bands, optimal band combination was adopted in fusion process. Also, the new strategy took only a few milliseconds in computing, which met real-time requirement. Finally results revealed that the new method achieved excellent fusion of finger-vein multispectral information providing higher finger-vein recognition accuracy.

A new method to verify infrared finger-vein patterns was proposed by Peng et al., (2012). First, select Gabor filter parameters with eight orientations to exploit finger-vein network, then extract vein patterns by fusion of two distinct orientation results. Second, use SIFT features to offset images rotation effect and shift impact during finger-vein verification. Finally, number of matching SIFT features between registered and test finger vein patterns is calculated as similarity measurement to verify personal
identification. Results revealed that EER was low at 0.46%, proving that the new approach was valid and effective for finger-vein verification.

A gray valley-shaped region search based extracting method analyzing the characteristics of human finger veins image using profile curve valley-shaped characteristics of finger veins image to achieve veins features extraction was proposed by Xianming et al., (2010). To obtain full extraction, image pre-processing was conducted and a system to test the algorithm and execution time based on DM6437 platform was established. Results revealed the algorithm as unique, easy to implement and ensured satisfactory effects for finger veins features extraction. Further, optimized algorithm execution time could be used in engineering applications.

### 2.3 MULTIMODAL BIOMETRICS USING FINGERPRINT AND FINGER VEIN

Enhancing off-line biometric signature verification using fingerprint assessment designed to match biometric fingerprint images applicable to static/image-based “off-line” human signature modality was proposed by Guest and Hurtado (2011). Verification performance was through a publically available signature dataset and was compared to three current static methods. Verification was assessed using four methods in multi-classifier system. Results showed the fingerprint method resulted in performance comparable with current methods and ensured great improvement in multi-classifier configuration.

Feature extraction using Gabor filter and recursive fisher linear discriminant with application in fingerprint identification was proposed by Dadgostar, et al., (2009) which presented a Gabor filter and RFLD algorithm based new feature extraction for fingerprint identification. The new process was assessed on images from bio-lab database. Experiments revealed that
compared to Gabor filter and PCA transform, applying RFLD to a Gabor filter in 4 orientations increased identification accuracy from 85.2\% to 95.2\% by nearest cluster centre point classifier with leave-one-out method. The new process had reduced computational complexity and high accuracy rates compared to texture features based traditional methods.

Score level fusion based multimodal biometric identification that addressed two issues related to score level fusion was suggested by Elmir et al., (2012). Performance of score level fusion based multimodal biometric system was compared to mono-modal voice, fingerprint modalities based biometric system and a feature level fusion of similar modalities based bimodal biometric system. Evaluation included efficiency and identification rate on a close group from test data. Results showed cumulative match characteristic curve.

A frequency-based approach for feature fusion in fingerprint or iris multimodal biometric identification systems to discriminate between subjects automatically, reliably and dependably based on target specific application was proposed by Conti et al., (2010). An innovative iris and fingerprint traits multimodal biometric identification system proposed was a state-of-the-art multi-biometrics advancement offering innovative features fusion perspective. A frequency-based method affects a consistent biometric vector, integrating fingerprint and iris data while a hamming-distance-based matching algorithm handled unified homogenous biometric vector.

An identification based on fusion fingerprints and face biometrics using LBP and GWN descriptors that developed a multimodal biometric recognition system proposed by Gargouri et al., (2011) combined face and fingerprint modalities. Face trait builds GWNs based features while LBP used finger print trait. Experiments proved that a weighted sum based fusion
produced excellent recognition performances, outperforming single biometric systems.

A low cost multimodal hand geometry, palm and finger print texture based biometric identification system that combined palm, finger print and the human hand’s geometrical features based multimodal biometric identification system was proposed by Ferrer et al., (2007). Right hand images were got through a commercial scanner with a 150 dpi resolution and geometrical features via binaries images with 15 measures. SVM verified it.

A Gabor feature fusion based new approach to finger-knuckle-print recognition presented a method for personal identification and identity verification suggested by Shariatmadar and Faez (2011) included Gabor filter bank, combining PCA and LDA algorithms and Euclidean distance measure. These were used for dimensionality reduction, feature extraction and classification. Identification and verification experiments results combining features of four fingers showed 98.79% and 91.8%, respectively proving the new biometric characteristic’s efficiency and effectiveness.

Finger-vein identification using pattern map and PCA was proposed by Beng and Rosdi (2011). Authors suggested a new PPBTF and PC based pattern map based approach for finger-vein recognition. Instead of getting finger-vein features from multi-filtered images, it leads to features from pattern map images. Experiments revealed that the new algorithm had higher identification rates compared to current method with only 40 features, and that pattern map represented finger-vein pattern effectively.

Comparison of iris recognition using PCA, ICA and Gabor wavelets was proposed by Shi and Gu (2010). It compared PCA, ICA and Gabor wavelets based feature extraction algorithm for a compact iris code, to generate optimal basis elements representing iris signals efficiently. The
methods coefficient was used as feature vector following which an iris feature vector was encoded into the iris code to store and compare individual iris patterns.

A framework for fingerprint and iris recognition using SVM and Extreme Learning Machine (ELM) based on score level fusion was suggested by Sangeetha and Radha (2013) where a SVM and ELM comparison based on score-level fusion methods was obtained. ELM ensured better performance in score-level fusion compared to SVM. It reduced system classification time. This work was accurate and useful for person identification applications.

Feature level fusion of fingerprint and face modalities using Gabor filter bank where a biometric authentication system was based on face and fingerprint modalities feature level fusion was proposed by Deshmukh et al., (2013). This used Gabor filter bank with 2 scales and 8 orientations, for directional features extraction from source data. Using a small set of Gabor filters lowered system processing time. Experiments were tried out on ORL face database and FVC2002 fingerprint database.

Fingerprint verification using Gabor co-occurrence features presenting an efficient GWT based algorithm for finger print verification for personal identification was suggested by Arivazhagan et al., (2007). GWT based method ensured local and global information in fixed length finger code. Finger print matching was through locating Euclidean distance between two corresponding finger codes and matching was fast.

Human authentication using face and fingerprint biometrics using employed product rule in investigations was suggested by Darwish et al., (2010). Final identification was through a nearest neighbour classifier that was effective. Results confirmed the approach achieving excellent recognition and fusion outperformed single modality based biometric identification.
A new type of multimodal biometric system using score level fusion to recognize face and irises images was proposed by Kim et al., (2012). Unimodal biometric systems suffered from problems due to variations in illuminations and devices, skin condition and environment. So, to overcome such limitations, author proposed a multimodal biometric system combining face and iris images. The new device captured both images simultaneously. Results proved that the new process performed better than face and iris recognition individually and also was an improvement over other combination methods.

System-On-Chip (SOC) Field Programmable Gate Array (FPGA) based implementation in multimodal biometric systems for authentication was discussed by Moganeshwaran et al., (2012). The new authentication system was resource constrained environment embedded. Traits like Fingerprint and finger vein were used in biometric system and all authentication checks were implemented in SOC FPGA. An embedded processor executed and information fusion was by score level matching. Experiments with the new system showed that accuracy was good with 0.33 % of Error Equal Rate (EER).

A multi-resolution approach to recognize humans using iris and palmprint patterns was proposed by Hariprasath and Prabakar (2012). Wavelet Packet Transform (WPT) was used for texture analysis. An adaptive threshold was used and WPT sub images coefficients were quantized into 1, 0 or -1 as iris signature which showed different irises local information. The biometric signature of code’s size was obtained at 960 bits when wavelet packets were used. Then new signature pattern was computed and matched against stored patterns.

An approach to improve texture features ability to recognize humans using palm prints was proposed by Wang and Sun (2012).
Riemannian geometry outcomes ensured palm lines details and their direction fields were constructed. As direction fields are palmprint image portions of textural features which improve the texture features distinctive ability. Then, a dual-tree complex wavelet transform-based local binary patterns are weighted by histogram method (DT -CWT based LBPWH) to ensure improved texture features. Experiments with the new method were evaluated to study the method’s effectiveness.

Integration of two modalities like facial thermograms and ear and both were extracted from same face simultaneously by Kumar et al., (2012). Rank level fusion combined characteristics of both modalities. Facial thermogram with infrared thermal faces captured by an infrared camera and second modality of ear point features were recorded by a digital camera. Both facial thermograms and ear images were normalized after locating ROI and features extracted using Haar wavelets and Scale Invariant Feature Transform (SHIFT) respectively. The new authentication system used 500 facial thermograms and ear images in the experiment resulting in 98% of Genuine Acceptance Rates (GAR) at 0.1% of False Acceptance Rate (FAR).

A method to enhance finger vein biometric system accuracy using multiple finger vein patterns for every person was introduced by Mohamed et al. Four fingers like two fingers each in the right and left hands used one identity. From recorded modality, finger region was segmented and each finger’s vein tree constructed using maximum curvature points in image profiles. The binary vein pattern from each finger was matched using the Phase Only Correlation (POC) method. Fusion methods were used to fuse multiple finger vein patterns of one identity score level.

A feature level fusion of face extracted features was proposed by Awang et al., (2013). As fusion leads to high dimensional combined features this is offset by LDA for feature extraction. Feature selection is performed
using Genetic Algorithm (GA) with a new fitness function. Results ensured an accuracy of 97.50% using concatenated features and optimization.

A fuzzy vault framework using iris, retina and finger vein templates for security aspects used by Geetika (2013) ensured stable with template longevity so that it could be used applications requiring high security. The new multimodal fuzzy vault used feature points fusion extracted from 3 traits like iris, retina and finger vein. The proposed vault’s security level was measured using min-entropy. A multimodal biometric prototype that captured a palm vein and three fingerprints simultaneously was proposed by Hamad et al., (2012). The modalities were evaluated as to whether the combination was statistically independent. Multimodal biometrics in many studies gave high recognition accuracy and population coverage merging different biometric sources and results were evaluated by false acceptance.