LIST OF FIGURES AND TABLE

Figure 1.1 Example of fingerprint image.............................................................4
Figure 1.2 Examples of palmprint image (a) on-line, (b) off-line.........................5
Figure 1.3 Example of Finger-knuckle print ......................................................7
   (a) Typical FKP Image from Hong Kong Polytechnic University database,
   (b) Extracted ROI from FKP image
Figure 3.1 Block diagram of the imprint recognition system..............................45
Figure 3.2 Steps illustrating pre-processing: ...................................................47
   (a) original image (b) binary image
   (c) boundary tracking (d) key points ($k_1$ and $k_3$) detecting
   (e) coordinate system and (f) the central part of a palmprint
Figure 3.3 Core point detection in fingerprint images........................................50
   (a) images with one core point detected,
   (b) two core points detected on images
Figure 3.4 Cropped fingerprint image to $128 \times 128$ pixels using its ..................51
   core point as the center
Figure 3.5 ROI extraction from FKP image.....................................................51
   (a) Original FKP image,
   (b) Cropped FKP image.
Figure 4.1 Typical 2-D Gabor filter response with eight orientations...............55
Figure 4.2 Typical 3-D Gabor filter response with eight orientations...............55
Figure 4.3 Gabor oriented palmprint features
   (a)-(h) Convolution of palmprint image $E_{x,y}$ with Gabor filters of ..........57
   eight orientations $\theta_k \in \{0^\circ, 22.5^\circ, 45^\circ, 67.5^\circ, 90^\circ, 112.5^\circ, 135^\circ, 157.5^\circ\}$
Figure 4.4 Reconstructed palmprint image .....................................................57
   (a) using four oriented Gabor features,
   (b) using eight oriented Gabor features
Figure 4.5 Dominant variance feature map at $\theta = 0^\circ$ for two different palmprint
   images...58
Figure 4.6 Gabor filters convolved with crop fingerprint image for ...............61
   $\theta_k \in \{0^\circ, 22.5^\circ, 45^\circ, 67.5^\circ, 90^\circ, 112.5^\circ, 135^\circ, 157.5^\circ\}$
Figure 4.7 Reconstructed fingerprint image .................................................62
   (a) Crop image, (b) Gabor feature with $\theta_k = 0^\circ$,
   (c) Normalized image with $\theta_k = 0^\circ$, (d) Filtered image,
   (e) Reconstructed image using four Gabor features,
Development of Multiple Hand Based Biometrics using Multi-resolution Framework

List of Figures

Figure 4.8 (a)-(c) Low quality fingerprints.................................................................63
(d)-(f) feature vectors for 0° Gabor orientation

Figure 4.9 Finger feature vectors
(a) original fingerprint, (b) cropped fingerprint, .................................................64
(c)-(j) finger feature vectors at

\[ \theta_i = \{0^\circ, 22.5^\circ, 45^\circ, 67.5^\circ, 90^\circ, 112.5^\circ, 135^\circ \text{ and } 157.5^\circ \} \]

Figure 4.10 Finger feature vectors
(a) original fingerprint, (b) cropped fingerprint,.................................................65
(c)-(j) finger feature vectors at

\[ \theta_i = \{0^\circ, 22.5^\circ, 45^\circ, 67.5^\circ, 90^\circ, 112.5^\circ, 135^\circ \text{ and } 157.5^\circ \} \]

Figure 4.11 Gabor filters convolved with crop FKP image for .............................66

\[ \theta_i = \{0^\circ, 22.5^\circ, 45^\circ, 67.5^\circ, 90^\circ, 112.5^\circ, 135^\circ \text{ and } 157.5^\circ \} \]

Figure 4.12 Dominant variance feature map at \( \theta = 0^\circ \) for two different FKP images....67

Figure 4.13 FAR and GAR at various thresholds......................................................68

Figure 4.14 Radon transform \( P_x(t) \) is the 1-D projection of \( f(x,y) \) at an angle \( \theta \) ....69

Figure 4.15 Line property (a) A 2-D function \( g(x,y) \), (b) Radon transform \( g(p,T) \) ...70

Figure 4.16 Radon projections at 0, 22.5, 45, 67.5 and 90 degree...........................71
obtained for two different palmprints and their respective hotplot.

Figure 4.17 Radon projections at 0, 22.5, 45, 67.5 and 90 degree ............................72
obtained for two different fingerprints and their respective hotplot

Figure 4.18 Radon projections at 0, 22.5, 45, 67.5 and 90 degree ............................73
obtained for two different FKP and their respective hotplot

Figure 4.19 Percentage FAR and GAR plotted at various thresholds....................74

Figure 4.20 2-D filtering analysis through separable scaling and wavelet functions.......76

Figure 4.21 Image decomposition (Dyadic partitioning) by 2-D DWT.......................77
(a) Original image, (b) First level, (c) Second level, (d) Third level

Figure 4.22 2-D Synthesis filtering for image reconstruction.................................78

Figure 4.23 The Haar (a) scaling function \( \Psi(x) \), (b) wavelet \( \psi(x) \)......................80

Figure 4.24 Daubechies scaling functions \( \Psi(x) \) (a) db2, (b) db5, (c) db10 ..........81
and Daubechies wavelet functions \( \psi(x) \) (d) db2, (e) db5 and (f) db10

Figure 4.25 Coiflet scaling functions \( \Psi(x) \) (a) coif1, (b) coif3, (c) coif5..........82
and Coiflet wavelet functions \( \psi(x) \) (d) coif1, (e) coif3 and (f) coif5

Figure 4.26 Symlet scaling functions \( \Psi(x) \) (a) sym2, (b) sym5, (c) sym8.............83
and Symlet wavelet functions \( \psi(x) \) (d) sym2, (e) sym5, (f) sym8
Development of Multiple Hand Based Biometrics using Multi-resolution Framework

Figure 4.27 Biorthogonal 1.3 wavelets (a) Decomposition scaling function $\Phi(x)$.............84
(b) Decomposition wavelet function $\psi(x)$, (c) Reconstruction scaling function $\Omega(x)$,
(d) Reconstruction wavelet function $\varphi(x)$

Figure 4.28 Cropped palmprint image its third level decomposition along.........................86
with signature (a) db4, (b) bior6, (c) coif5, (d) haar, (e) rbio6.8, (f) sym8

Figure 4.29 Fingerprint image its third level decomposition along with signature ...........88
(c) coif5, (d) haar, (e) rbio6.8, (f) sym8

Figure 4.30 Cropped FKP image its third level decomposition along with
signature.......90
(a) db4, (b) bior6, (c) coif5, (d) haar

Figure 4.31 Percentage FAR and GAR plotted for palmprint at various.......................91
thresholds for different wavelets

Figure 4.32 Percentage FAR and GAR plotted for fingerprint at various .....................91
thresholds for different wavelets

Figure 4.33 Percentage FAR and GAR plotted for FKP at various.........................92
thresholds for different wavelets

Figure 5.1 Definition of PCA.............................................................93

Figure 5.2 Magnitude plot of Eigen values in descending order...............................95

Figure 5.3 The covariance matrix construction using PCA........................................96

Figure 5.4 A comparison of PCA and FLD for a two class problem.............................97

Figure 5.5 Different Eigen vector images of Palmprints...........................................98

Figure 5.6 Mean palm image..............................................................................99

Figure 5.7 Some examples of the eigenpalms .......................................................99
sorted with respect to decreasing eigenvalues

Figure 5.8 Some examples of the eigenfingers.....................................................100
sorted with respect to decreasing eigenvalues.

Figure 5.9 Some examples of the eigenFKPs, ......................................................100
sorted with respect to decreasing eigenvalues.

Figure 5.8 Recognition accuracy with PCA.......................................................102