Chapter 7
Thesis Summary and Conclusions

This chapter presents thesis summary and also future scope of work highlighting several open questions in the research field.

7.1 Summary and Conclusions

The goal of the research presented herein is to examine the design issues of multibiometric systems, and to develop a frame work for multibiometric template protection. To achieve this goal, detailed investigation of the multiple sources of information and its fusion strategies in multibiometrics have been extensively investigated along with the biometric template security issues.

The main contribution of the research work carried out in this thesis is the development of information fusion method at match score level. The existing concept of fuzzy integral is enhanced by generalizing the type-1 membership function to interval type-2 membership function and a match score level fusion method called interval type-2 fuzzy integral (IT2-FI) within the interval type-2 environment is developed. Further, a framework for cancellable multibiometric template security based on BioHashing has been proposed to facilitate secure multibiometric system.

In the present work, iris image is used as one of the biometric trait. Iris images were segmented using local grayscale intensity threshold method and the Hough transform with Canny edge detection. The segmented iris images were normalized with the windowing technique and the Daugman's rubber sheet model. Subsequently, features were extracted using four statistical methods *viz*. Single Value Decomposition (SVD), Principal Component Analysis (PCA), Automatic Feature Extraction (AFE) and Independent Component Analysis (ICA) and a Discrete Wavelet Transform (DWT) *viz.* 'db2' filter. The extracted patterns (i.e. iris patterns) were classified using a Feedforward Backpropagation Neural Network (BPNN with *tansig* transfer function) and Support Vector Machines (SVM) with Radial Basis Function (RBF) kernel with

different dimensions and different number of classes and, a comparative study was made over the CASIA-IrisVI database. The performance of the different feature extraction methods with different dimensions (i.e. 3D, 10D, 20D and 40D) and different number of classes (varied from 3 to 50) were analysed using BPNN and SVM with RBF based on the correct classification rate. The study demonstrates that SVM with RBF works better than BPNN in high number of classes and ICA is the best feature extraction method among the five methods for both BPNN and SVM with RBF. Also, the running time of SVM with RBF is less than that of BPNN for the considered CASIA-IrisVI dataset. The iris patterns obtained with the ICA feature extraction method were employed in the multibiometrics experimentations.

The design issues of multibiometric systems *viz*. match score fusion strategies and biometric template security have been investigated in this thesis. A match score fusion approach based on interval type-2 fuzzy integral (IT2-FI) has been proposed for multibiometric system. The performance of the proposed IT2-FI is evaluated in multi-classifiers multibiometric system and multimodal biometric system. In the multi-classifiers biometric system, iris patterns based on PCA and ICA features are classified by using three classifiers *viz*. fuzzy k-NN and two neural networks, BPNN-1 and BPNN-2, with *logsig* and *tansig* transfer functions respectively. The proposed interval type-2 fuzzy integral (IT2-FI) has been employed to combine the match score of the three classifiers and its performance has been compared with the other fusion methods *viz*. the sum rule, max-rule, product-rule and type-1 FI. In the multimodal biometric system, three biometric traits i.e. fingerprint, iris and signature were employed and their matching scores were combined using IT2-FI. The fingerprint and signature match scores were taken from the MCYT-score database and iris matching scores were taken from the multi-classifiers biometric system with the CASIA iris database. From the experimental results, it is observed that the proposed IT2-FI outperforms the four fusion methods including the type-1 FI in terms of EER and FRR.

Further, biometric template protection schemes including biometric cryptosystems, biometric feature transform, cancellable biometric, data hiding techniques were reviewed. A new approach to cancelable multibiometric based on BioHashing is proposed and is tested with biometric systems including iris recognition system and fingerprint recognition system. The proposed cancelable biometric is employed to transform the unibiometric and multibiometric template and the

transformed cancelable templates were classified using SVM with RBF Kernel. The performance of the proposed CB is compared with the base BioHashing method at best, stolen-key (S-Key) and stolen-biometric (S-Bio) scenarios. From the experimental results, it is observed that the proposed CB outperforms base BioHashing method in terms of EER and FRR and is a promising approach for biometric template protection.

7.2 Future Scope of Work

The research results presented herein demonstrate the superior performance of the proposed match score level fusion strategy and cancelable multibiometrics template protection scheme that facilitate the design of reliable and secure multibiometric systems. It is believed that the techniques proposed in this thesis can be further expanded as following:

- The proposed IT2 FI fusion strategy can be used in designing other types of multibiometric system *viz*. multi-sensor, multi-instance, multi-sample biometric systems.
- There is no structured methodology available for the selection of classifier in multi-classifier biometric system and algorithmic parameters. Standardized methodology of selecting classifiers and automation of algorithmic parameter selection may be developed.
- The proposed cancellable multibiometric can be used in other biometric modals and multiboimetric systems.