Chapter 7

Conclusions and Future Work
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7.1 Research Contributions

Researchers have invested a substantial amount of effort in studying fingerprints in the context of forensics, computer vision, image processing, pattern recognition, and biometrics. This seemingly simple pattern of ridges and valleys on the tip of a finger has, therefore, received considerable attention. In spite of this attention, the problem of automatic fingerprint matching continues to harbor plenty of challenges. In this thesis we have approached the challenges in fingerprint matching from an information fusion perspective.

- We first developed a hybrid matcher that combined the minutiae and texture information present in a fingerprint. In the proposed technique, the texture information was represented using ridge feature maps which could also be utilized to align and register pairs of fingerprint images. The hybrid system presented here was
shown to enhance the matching performance of a fingerprint system. One of the advantages of using a hybrid approach is the complementary nature of the information being combined. This aids in decreasing the false accept rate (i.e., the false match rate) as follows: by examining the underlying ridge information via ridge feature maps after aligning the images using minutiae points, the integrity of the matcher is improved.

- We then described a mosaicking scheme that integrated the information present in two impressions of a finger. In this technique, fingerprint images were viewed as range images, and the iterative control point (ICP) algorithm was used to register them. The technique presented here utilized minutiae points to determine an initial alignment between image pairs. The mosaicking process resulted in a composite template which was more elaborate than the individual images. Mosaicking is an essential component of a fingerprint system since it elegantly consolidates the information available in several partial prints.

- We have shown that the SIKP operator can be used for fingerprint feature extraction and matching. We have performed fingerprint matching in two steps: i) point-wise match and ii) trimming false matches with geometric constraints. The fusion with a minutiae based matcher shows significant performance improvement on two public domain databases. We believe the performance improvement due to fusion is possible because the
sources of information used in minutiae and SIKP based matchers are significantly different. SIKP shows a good possibility of extending minutiae based or minutiae related fingerprint representations.

- To account for non-linear distortions in fingerprints, an “average” deformation model was proposed. In this approach, a fingerprint impression (baseline) was compared with several other impressions of the same finger in order to determine the “relative” non-linear deformation present in it. The average deformation model was developed using thin-plate splines (TPS) and ridge curves were used to establish correspondences between image pairs. The estimated average deformation was utilized to pre-distort the minutiae points in the template image before matching it with the minutiae points in the query image. The use of an average deformation model resulted in a better alignment between the template and query minutiae points. An index of deformation was also defined for choosing the deformation model with the least variability from a set of template impressions corresponding to a finger.

- Finally, the fingerprint evidence of a user was combined with the face, iris and signature traits to design a multibiometric system. A multibiometric system not only improves matching performance as was demonstrated in this thesis, but it also addresses the problem of non-universality and spoofing that are prevalent in unimodal systems. Biometrics systems are widely used to
overcome the traditional methods of authentication. But the unimodal biometric system fails in case of lack of biometric data for particular trait. Thus the individual scores of four traits are combined at classifier level and trait level to develop a multimodal biometric system. The performance table and accuracy curve shows that multimodal system performs better as compared to unimodal biometrics with accuracy of more than 97%.

7.2 Future Research

Significant efforts are currently being undertaken to integrate biometrics into the fabric of society (e.g., National ID card, US-VISIT program, etc.). It is, therefore, imperative that researchers and practitioners systematically study the engineering aspects of biometric systems that would ensure their successful installation in real-world applications. The social and legal implications of biometric systems will also have to be separately studied and understood, before deploying these systems on a large scale.

We conclude this thesis by suggesting possible ways in which the research presented here may be expanded in order to build robust fingerprint (biometric) systems.

1. The hybrid matcher utilizes square tessellations to compare the texture (i.e., ridge flow) information across images. In view of the non-linear deformations present in fingerprint images, it would be
instructive to ‘distort’ the square cells in a non-linear fashion prior to the matching process. In fact, the average deformation model suggested in this thesis may be used to pre-distort the square tessellations in the template image.

2. The performance of the hybrid matcher is closely related to the accuracy of the image registration (alignment) process. In the procedure presented in this thesis, it is the minutiae points that are used to accomplish registration. However, for the sake of robustness, multiple alignment hypothesis may be used to determine the transformation parameters that best relate two fingerprint images. For example, the minutiae points, ridge curves, orientation field, ridge feature maps and singular points could all be used to generate an alignment hypothesis. These various hypothesis may then be consolidated to recover the true transformation parameters. The availability of multiple alignment hypothesis is especially useful when poor quality fingerprint images are involved.

3. The fingerprint mosaicking technique utilizes partial impressions of a fingerprint to construct a more elaborate one. Given several partial impressions of a finger, there is no systematic technique for determining which of these should be used for generating the composite template. Thus, a method to automatically select candidate impressions for mosaicking would improve the integrity of the composite template. The candidate selection process could also be used to perform automatic template selection and update in a biometric
system.

4. The average deformation model for a fingerprint may be used to detect the presence of a fake finger on the sensor. The minutiae points on a fake fingertip may not be distorted in the same way as those present on a live fingertip. (This is true, for example, when the material used to synthesize the fake fingerprint does not exhibit "skin-like" properties). Therefore, the system may request a user to present multiple impressions of a finger during verification and derive the relative non-linear distortion between the acquired impressions. These distortions can then be compared with the average deformation model for the finger in order to observe if they are similar. A lack of similarity might indicate the presence of a fake finger.

5. The effect of score normalization on the matching performance of a multibio-metric system has to be studied. In this thesis, a simple min-max normalization technique is utilized to transform the matching scores of multiple modalities into a common domain (i.e., all matching scores are mapped in a linear fashion to the [0,100] range). However, other robust normalization techniques have to be examined in order to offset the effect of outliers on the matching performance.

6. Fusion at the matching score level is the most popular approach to multibio-metrics due to the ease in accessing and consolidating the scores generated by multiple matchers. However, fusion at the feature extraction (representation) level is expected to be more effective due to
the richer source of information available at this level. Therefore, it is important to study the possibility of fusing information at this level. Concatenating compatible feature sets would be one way to integrate information at this level. Integration at this level is not without its challenges. For example, it would be difficult to concatenate two incompatible feature sets like the eigen-coefficients (for face) and minutiae points (for fingerprint).