Chapter 6

Conclusions and Further Enhancements

6.1 Conclusions

Various methods and algorithms have been investigated for illumination invariant face recognition. Existing algorithms are improved by using adaptive smoothing and fuzzy based techniques and modified algorithms have been presented. Three different dimensions of varying illumination handling have been addressed. First, retinex theory based algorithms have been investigated and improved for varying illumination normalization. Second, algorithms for extraction of illumination invariant features from face images which are illuminated with varying illumination have been presented. Third, an approach is proposed which combines fuzzy weighted normalization with fuzzy measure based adaptive retinex algorithms. To assess the performance improvement and validate the effectiveness of algorithms, experiments have been performed on Extended Yale B face database and CMU PIE face database.
One of the major contributions of the thesis is investigation and improvements in retinex based algorithms. Fuzzy homogeneity measure has been introduced in ASR and ASQI algorithms in place of local in-homogeneity measure to preserve important facial features during illumination normalization. UIQI demonstrates that, quality of images normalized using fuzzy measure based algorithms is better that quality of images normalized using in-homogeneity measure based algorithms. The reason is fuzzy measure considers more precise relative importance of neighboring pixels for preserving important features. It is found that overall performance of fuzzy homogeneity measure based adaptive algorithms (FASR, FASQI) is better than simple adaptive algorithms (ASR, ASQI). Experimental results in terms of performance parameters like EER, RR, and FAR demonstrates modified algorithms have significantly improved performance of face recognition problem under varying illumination. It is observed from Tables and ROC’s that, for simple lighting conditions, ASQI based algorithms performs better where as for complex lighting conditions ASR based algorithms performs better. The reason behind such performance is that, ASR and FASR uses logarithmic reflectance which performs non-linear transformation for varying illumination and hence it has capability to handle medium and complex lighting conditions with more accuracy compared to ASQI and FASQI. The experimental result on both the database confirms consistency in performance of modified algorithms. It is also observed that, as lighting conditions become complex, performance starts degrading irrespective of algorithms.

Another major contribution is investigation of illumination invariant feature extraction using completed modeling of local binary pattern framework. Two variations of CLBP algorithm have been proposed and modified algorithm Ft-
CLBP and ASR-CLBP have been presented in this thesis. Parametric evaluation of completed local binary pattern and fuzzy threshold based local binary pattern illustrates that former is more sensitive to complex lighting conditions compared to later one. Evaluation results of CLBP and FtCLBP demonstrates that, for simple illumination conditions CLBP performs better whereas for complex illumination conditions FtCLBP performs better. This is because CLBP is more sensitive to complex illumination conditions, as said previously. Comparison of CLBP and ASR-CLBP demonstrates that, features extracted from illumination normalized images are more similar to enrolled images compared to features extracted from images without normalization. Performance of ASR-CLBP is better than FtCLBP in terms of EER, RR, and FAR. Neighborhood size of a pixel in a given local window is an important factor in extracting illumination invariant features. Smaller neighborhood size gives better recognition rate when illumination conditions are complex as in FtCLBP (Fig. 4.11, Page-102) and larger neighborhood size gives better recognition rate when illumination conditions are very simple or illumination effect is reduced to almost NIL, as in ASR-CLBP (Fig. 4.14, Page-105). It was observed that, ASR-CLBP improves performance compared to FtCLBP at additional computational cost which is incurred in adaptive illumination normalization during preprocessing phase.

One another contribution of the thesis is to identify the amount of illumination on different parts of the face image in terms of fuzzy weight and then normalize it using the fuzzy weight matrix. Pixels in illuminated face regions are clustered into different segments by applying clustering algorithms KM and FCM, separately. Smaller value of fuzzy entropy measure of FCM segmented images compared to that of KM segmented images, demonstrate that FCM based
segmentation result is better than KM based segmentation. Pixels are assigned weight in terms of membership value with respect to segmented regions to signify amount of illumination. The experimental results shown in terms of RR and EER illustrates the usefulness of segmentation based proposed methods.

The selection of value of weighting constant $c_1, c_2, \text{ and } c_3$ is very important. If these constant are not properly selected, performance of algorithm may degrade drastically. The constant can be selected experimentally or using some optimization techniques like genetic algorithm or particle swarm optimization. KM-FASR performs poor compared to FCM-FASR because of less accurate segmentation results, and indirectly improper fuzzy weights for illumination normalization. The significant improvement in performance of FCM-FASR validates the effectiveness of fuzzy weighted adaptive illumination normalizing algorithm. The overall results demonstrates that, presented fuzzy weighted adaptive hybrid algorithm provides better performance than fuzzy measure based adaptive algorithm. The presented method (FCM-FASR) is suitable for complex lighting conditions and hence it should be used with other illumination normalization method selectively based on illumination condition complexity. Statistical measure like UIQI can be used to determine quality of image or illumination condition complexity of face image.

In summary, the thesis contributes to the study, investigation and development of novel adaptive and fuzzy based algorithms for improving the performance of face recognition task under varying illumination conditions.
6.2 Further Enhancements

There are a number of useful extensions that can be added to the present research work. A few fuzzy based modifications of existing algorithms have been presented and used for handling varying illumination problem in face recognition application domain. Yet there is scope of improvement in the performance of face recognition through improvement in presented methods and algorithms. The possible additions to the present work are stated below:

- The fuzzy based adaptive retinex algorithms can be further improved through multi-scale analysis of illuminated images to handle the key challenge of varying illumination.

- Retinex based adaptive methods with other soft computing methods like support vector machine, extreme learning matching, etc. can further enhance accuracy of recognition.

- The fuzzy based adaptive retinex algorithms may be hybridized with optimization techniques for selecting appropriate parameters like amount of discontinuity to be preserved.

- The CLBP and FtCLBP framework may be modified to include fuzzy local binary pattern or fuzzy ternary patterns to extract features which may provide better discrimination power.

- Local binary patterns may be improved by higher order local pattern and multi-scale analysis to extract illumination invariant features from face images.
Chapter 6. Conclusions and Further Enhancements

- Adaptive fuzzy segmentation based illumination normalization is one of the very promising areas of future work. Advanced segmentation techniques with properly selected weighting constant may improve performance of face recognition task.

- The presented algorithms may be extended to handle varying illumination problem for 3-D face recognition.

- In this thesis, the presented methods are used for face recognition application. But, the same methods can be used for handling varying illumination problem in any image processing application.