Chapter 7

Conclusions and Future Work

7.1 Conclusions

Retinal image analysis has become a potential research area in recent years as diabetic population is exponentially increasing. For effective and maximum reach out of clinical diagnostic benefits especially in developing countries it has become essential to develop the computer based diagnostic systems with reliable performance and acceptability.

In this thesis, we have proposed two feature based algorithms for retinal image registration. Two techniques for segmentation of retinal blood vessels have been developed and discussed. Also a method for classification of hard exudates is presented.

- In the first technique of registration the moment invariant features are used for registration of retinal images. From the results the moment invariants features are proved effective for retinal image registration. In the present algorithm the process of finding matched pair of control points involves identification of one out of \( n \) bifurcation point based on comparison of feature vectors. This apparently takes lesser computations and reduces the overall registration time. The algorithm also works satisfactorily even in case of lesser number of control points.

- In the second technique for registration of retinal images directional gradients around salient vessel bifurcation points are used as feature. It is observed that directional gradients around a vessel bifurcation point exhibit rotation invariance. As the size of the feature vector is
8 × 1 this technique utilizes minimal computations. This technique produces comparable results.

- A retinal blood vessel segmentation algorithm using gradient co-occurrence features is proposed. The gradient co-occurrence features truly represent primary, secondary retinal blood vessels and most of the retinal capillaries. Since the gradient co-occurrence features consider differences in individual grayscale values of the pixels as well as the joint probabilities of pixels; the probability of retaining retinal capillaries has increased. This has resulted in increase of the number of true positives improving the overall performance.

- A blood vessel segmentation algorithm based on pixel gradient is presented. Intensity difference between the vessel pixels and non-vessel pixels (background pixels) lead to the separation of most of the vessel pixels. Therefore the gradient at the pixel has been explored as feature for vessel pixel segmentation. As the local grayscale intensity variations in the background are also captured by the gradient, some noise is introduced leading to misclassification and affecting the overall accuracy.

- A method for classification of hard exudates using matched filter enhanced features and maximum likelihood estimator is proposed. The algorithm produces a maximum registration error of less than seven pixels. The algorithm works effectively in case of non-uniform illumination. With proper training the method can be used for classification of other pathologies associated with DR.
7.2 Future Work

In the work presented in the thesis various feature based techniques for retinal image analysis have been presented and discussed. In Chapter 4 and 5 we have used pixel gradient as a primary feature for vessel segmentation. This work may be extended to determine a suitable combination of pixel gradient with another feature to form a composite feature for vessel segmentation which may result in better performance. The hardware realization for determining the progression of DR by way of identifying exudates. A low cost automated retinal screening set up comprising of a facility to determine progression of DR along with telemedicine feature.