CHAPTER-7 CONCLUSION AND FUTURE WORK

The chapter presents the conclusions of this thesis and suggestions for potential future research in the field of an automatic abnormality detection system for capsule endoscopy.

7.1 Conclusions

Machine learning in healthcare is trending significantly mainly due to its ability to process huge data and provide meaningful clinical insights. This ability is beyond the scope and ability of human beings. One such problem of machine learning in healthcare capsule endoscopy. With the objective to provide fast, accurate and precise diagnosis this thesis presents an automatic abnormality detection system for CE. The contributions towards image restoration, segmentation, feature selection, data reduction, and multi-class classification are highlighted in this thesis.

Chapter 1 presents the introduction to CE, motivation to work upon this problem, a brief problem statement, objectives and contribution of the thesis. It concludes with the organization of the thesis.

Chapter 2 presents the required theoretical background to study various aspects of the CAD system in CE. This mainly involved the types of features and performance metrics used to evaluate different studies. It then presents a detailed literature review on all computer vision and machine aspects of CE with a special emphasis on CAD systems for CE. It concludes with the current status and future challenges in each of the aspects.

Chapter 3 presents a framework for the restoration and enhancement of CE images using partial differential equations based filters. It focuses on Gaussian noise, motion blur and illumination related noises present in CE images. It further presents a controlled mechanism to smooth the CE images for noise removal and also restore lost high-frequency components. In the pursuit of restoration, some artifacts were introduced by the methods involved but they were also taken care systematically by providing a suitable solution.

Chapter 4 presents a generic segmentation approach based on Gaussian Mixture Model and the improved Expectation-Maximization method. The term generic signifies its capability to extract RoI from any normal or abnormal CE image. The solution ensures that the process is not stuck at local minima; that a solution is achieved and a penalty is imposed in case of a deviation from the objective. The algorithm outperforms state-of-the-art techniques for segmentation. It can precisely distinguish between black regions and dark red regions where other techniques fail. To demonstrate the efficacy of the proposed segmentation method we further extend the work to present feature selection and a fusion of feature method and demonstrates the performance of the multi-class classifier system.

Chapter 5 presents an HVLC based feature selection and data reduction approach with reference to ulcer detection in CE. It reduces the obtained feature set by 96.53%. Even with such a reduction in data, the proposed method outperforms five other feature selection techniques. Further, the chapter shows the performance of the classification system for ulcers in CE with reference to various classifiers. This approach can be used independently for data reduction and feature selection.

Chapter 6 presents a multi-class classifier system for a CE. This chapter provides an automatic abnormality detection system for CE using conventional machine learning as well as deep learning. It presents a hybrid model of the conventional machine learning and transfer learning mechanism. It performs with an accuracy of 96.89% and an F-measure of 96.45%. Moreover, the false positives are reduced drastically.

Overall the thesis concludes with summarizations of all aspects for the design and development of an automatic abnormality detection system for capsule endoscopy. It proposes a framework to de-noise the CE endoscopy images while restoring the high-frequency components for improving the quality of input image for post-processing. It then proposes a generic segmentation technique with GMM and improved EM to segment any CE image unlike a specific abnormality. The performance of segmentation is taken one step further towards feature selection, a fusion of feature and multi-class classification system capable of detecting bleeding, ulcer, angioectasia and normal. An HVLC based feature selection technique is used with a reference to ulcer detection which reduces the data by 96.53%. It also outperforms the state-of-the-art feature selection techniques. Finally, the thesis shows a hybrid system built by the confluence of conventional machine learning and transfer learning technique of deep learning. The proposed system outperforms conventional technique as well the deep learning-based technique and it performs with an accuracy of 96.89% and an F-measure of 96.45%. Notably, the false positive is drastically reduced, and most importantly, none of the abnormal images, i.e., angioectasia, ulcer, or bleeding, are misclassified as normal. Thereby the false negative is nil.

7.2 Future Work

In future, few experiments listed below may be carried out:

- In classification part, Random Forest or a boosting approach may be employed to result may be analysed.

- In case of un-balanced data problem, techniques such as SMOTE (Synthetic Minority Oversampling Technique) can be used.
- For noise removal and image enhancement, deep super-resolution methods can be explored.

With the advancements in IoT, one can work towards developing a domestic diagnosis tool for CE. Just as a blood pressure monitoring system and a diabetes monitoring system one can work towards a domestic biomedical tool for diagnosis of GI tract. The capsule can be injected and the data can be received in smartphones or a smartwatch. The light machine learning models like one proposed in the study which inspires from MobileNet can be used in the smart devices to produce a preliminary report of GI tract abnormalities.

Also, the technology can be expanded to provide a remote diagnosis to geographically distant and isolated places where an expert on the subject may not be available. Clinics can be developed with operators aware of the procedure to perform a CE and collect the receiver's data and store it digitally. The data can then be uploaded to an automatic abnormality detection system for preliminary diagnosis.