Chapter 6

Conclusion

A complete procedure for heart sound analysis was developed based on the pattern recognition approach and new approach to segmentation of heart sound was proposed. The proposed segmentation method does not require the type of each FHS to be identified, is not based on the assumption that systole is shorter than diastole that is usually made in many studies, and is robust to all heart sound types: from normal to severe murmur. This study also apply PCA analysis and bagging classifier technique to improve the classification performance. Experiments was conducted to determine the optimal configuration for the classifier. This optimal configuration yield a performance of 95.7% accuracy, 91.1% sensitivity and 100% specificity. Given this level of performance it is reasonable to say that the proposed method is ready to be tested on real patient in an actual hospital. The advantages of this work are:

1. The segmentation method make no assumption about the cardiac cycles and is robust to different type of heart sounds
2. There is no need to perform complicated envelope analysis of heart sound signal
3. The proposed method achieved good performance for a large variety of heart sound types.

And the shortcomings of this work are:

1. Only classifier heart sounds as normal or abnormal, with no diagnosis about the type of the disease (multi-class classification).
2. The training set is relatively small
3. The cross-validation time is quite long, around 250 to 300 seconds.

6.1 Comparison with Other Studies

Comparison among different studies in the field of heart sound analysis is difficult, mainly because there is no ”standard heart sound set” on which different algorithms can be tested fairly. Also, the way of reporting the performance can be different, some studies report result based on the number of heart sounds, while some report result based on number of feature vectors (often one feature vector is extracted from each cardiac cycle, so there can be more than one feature vector per heart sound). Many studies rely one manual segmentation or segmentation using the ECG signal, thus quoting classification accuracy alone would be

unfair for those that use automatic segmentation as in this work. Considering all this difficulty, this work is compared to the study in [16] that is quite similar to it. In that work heart sounds were classified into three types: normal, systolic murmur and diastolic murmur, they reported an average classification accuracy over three different datasets of 97%. This number of was based feature vector unit, not heart sounds unit and the study did not incorporate abnormal heart sound there are non-murmur types (S3, S4, systolic click, etc). This shows that the proposed method in this work is on par with results reported in the literature, while being applicable all types of abnormal heart sounds.

6.2 Further Work

The work in this research up to this point had provided a proof of concept for the proposed heart sound analysis method. All of the software are currently in MATLAB code (see appendix A). Further work can be divided into two parts: practical and research. For practical aspect, further work include implementing the software so that it could be run independently out of the MATLAB environment and adding a GUI to make the system more user friendly. This is so that the system could be tested on live patients in real hospital environment to verify its effectiveness in real-life situation.

For research aspect there are several possible directions. In a two classes problem considered in this work, it is possible to solve such problem using "single class classification" approach, where the training data consists of samples from only a single class. In the case of heart sound analysis, this would mean collecting only samples of normal heart sounds, then perform segmentation and feature extraction as usual. Once the set of training vectors $\mathbf{X}$ is obtained, a hypersphere that tightly encloses the training vectors is defined. Any new feature vector that lies inside this hypersphere is considered normal, while those that lie outside is considered abnormal. Using this approach there would be no need to collect data from ill patients, which is difficult to obtain in large quantity. Another possible direction is to borrow from speech recognition, using linear predictive coding together with sliding windows to extract feature vectors without any segmentation of heart sound.