Chapter 6

Conclusion and Future Directions

This chapter presents a summary of main contributions of this thesis along with promising directions for conducting future research in the early classification of time series.

Conclusion

This thesis has studied early classification problem for sensors generated MTS. Although the early classification problem remained of a great interest to the researchers, its solutions are still lacking to handle some important challenges of MTS such as components of different length, faulty data components, and presence of unseen classes. The components of different length are due to the different sampling rate of the sensors that generated the MTS. Similarly, the faulty data components are generated from the faulty sensors. Next, the unavailability of training instances of a class can lead to the presence of unseen class. The main objective of this thesis was to develop the early classification approaches while handling these challenges of MTS.

In this thesis, we have developed probabilistic approaches for solving the early classification problem while allowing the user to set the desired level of accuracy. The strengths of the proposed approaches are the estimation of class-wise MRLs by optimizing the tradeoff between accuracy and earliness, and incorporation of correlation

among the components. Beside that we collected three real-world datasets including road surface, human activities, and washing machine faults, for validating the effectiveness of the proposed approaches. To summarize, this thesis has achieved the objectives of the early classification for MTS while addressing the stated challenges.

In chapter 2, we reviewed the state-of-art solution approaches for the problem of early classification of time series. We divided the existing approaches into four categories: prefix based, shapelet based, model based, and miscellaneous. We also provided a comparative summary of early classification approaches for MTS using the parameters such as interpretability, reliability, and correlation.

In chapter 3, we addressed the problem of early classification for the MTS with the components of different length that are generated by the sensors of different sampling rate. An ensemble early classifier is built by estimating the class-wise MRLs for the given training dataset. These MRLs are estimated with the help of posterior class probabilities obtained from GP classifier. A class forwarding method is also incorporated with the ensemble classifier to capture the correlation among the components of MTS. Later, we collected a road surface dataset by attaching the sensors of different sampling rate to the vehicles. Finally, the effectiveness of the ensemble classifier is validated on the collected and existing real-world datasets. The experimental results are convincing enough to show that the proposed approach can classify an incomplete MTS with the components of different length.

In chapter 4, we mainly focused on the identification of faulty components by using ARIMA model. In particular, we proposed a fault-tolerant early classification approach for classifying an incomplete MTS which may consist of faulty components. The proposed approach constructed a set of classification models with the help of GP classifier and k-means clustering. The classification models also incorporated a concept of partial ordered set for pruning the irrelevant components from the MTS. Later, we developed an android application to collect a dataset of human activities. Finally, the performance

of the proposed approach is evaluated by classifying the ongoing human activities before their complete execution. The experimental results indicated that the approach is able to achieve desired level of accuracy and earliness even when the MTS has many unreliable or faulty components.

Finally, in chapter 5, we focused on to classify an incomplete MTS even when it belongs to an unseen class for which there exists no training instances in the dataset. We proposed an early classification approach with the incorporation of a concept of ZSL. According to the ZSL, the semantic information of the seen classes can be utilized for the identification of unseen class label. We extracted the semantic-information in terms of attributes which are the most distinctive subsequences of the time series. In particular, an attribute learning model is developed and incorporated with the proposed approach to handle the unseen classes. Later, we validated the effectiveness of the approach for early classification of unseen faults in washing machines.

Future Directions

This thesis points out several important research directions for early classification of MTS. We list some of the promising extensions of our work, as follows.

- This work does not consider interpretability of the classification results while developing the early classification approach. Interpretability helps to decide suitability of the solution approach for many applications, including medical. Incorporation of interpretability in early classification while optimizing the tradeoff between accuracy and earliness, can be a potential future work in this area.
- We have assumed the balance distribution of MTS instances among the classes in the training dataset. In some applications such as ECG classification where abnormal class may have much lesser instances than normal class, it becomes essential to handle the imbalance distribution of instances before building the classifier. The development of an early classification approach with the imbalance

distribution of instances can be a part of the future work.

- As deep learning techniques have automatic feature extraction capabilities, they can employed for building a better early classification model for identifying the MTS of instances of unseen class. It also gives a new direction towards enhancing capabilities of the early classification models, which will bring further improvement in this area.
- Incorporating a concept of transfer learning in the early classification framework while utilizing the correlation among the components of MTS, is a challenging work yet to be explored in the future.