CHAPTER-5

CONCLUSION AND FUTURE SCOPE OF RESEARCH

This thesis explores the multifaceted landscape of HAR using wearable sensors, shedding light on its significance and challenges. In the era of Industry 4.0—also called the Fourth Industrial Revolution or 4IR, HAR powered by wearable sensors, has the capacity to revolutionize healthcare, sports and fitness, security, IoT, IIoT, and smart environments. The present thesis explores the significant contribution of HAR in recognizing different daily activities. The thesis covers various special temporal analysis of the sensor data which leads to better recognition of these activities.

The present thesis also presents an eXplainable, cost-efficient model which can be implied in the real-world environment for the real time recognition of the HAR activities. The thesis's findings will spur design engineers to implement the model on the hardware for further usage.

5.1 Chapter-wise Summary

Chapter 1 and Chapter 2 presents the introduction, encompassing a brief literature review covering the evolution of HAR in wearable sensors, the objective and problem statement. This chapter also includes the basic working principle of HAR and their application in various domains. Various State of the art models have been discussed in these Chapters. The concept of eXplainability which helps in uncovering the black box nature of these models, followed by the dataset description, framework, and the evaluation metrics are discussed. This discussion aims to provide new readers with a preliminary understanding of the concepts involved in the HAR.

Chapter 3 presents a novel approach Seq2Dense U-Net for analyzing sequential inertial sensor data for HAR. The essential highlights of the chapter are as follows.

- The use of a segmentation model for the classification of different activities.

- We introduced a classifying block in the existing U-Net architecture for the task of activity recognition.
- The study was performed on the UCI-HAR, UCI-HAPT, mhealth and Sanitation dataset.
- The results obtained in this study are as follows:
    - On the UCI-HAR the accuracy score is 0.9547, precision is 0.9414, recall is 0.9406, F1 score as 0.9406 followed by MCC and Kappa score as 0.9487 and 0.9486, respectively.
    - On the sanitation dataset, the accuracy score is 0.9095, precision is 0.9031, recall is 0.9000, F1 score is 0.9011 followed by MCC and kappa score as 0.8884 and 0.8883, respectively.
    - On UCI-HAPT dataset, the accuracy score is 0.9474, precision is 0.9393, recall is 0.9383, F1 score is 0.9379 followed by MCC and kappa score as 0.9274 and 0.9272, respectively.
    - On mhealth dataset, the accuracy score is 0.9011, precision is 0.9121, recall is 0.9010, F1 score is 0.8928 followed by MCC and kappa score as 0.8950 and 0.8918, respectively.
- A comparative study with SOTA models on the latest metrices for extensive evaluation of the model is also presented.
- The depth analysis of the network is also performed to find the optimum depth of the architecture.

Chapter 4 presents an eXplainable self-attention based spatial temporal analysis of the inertial signals for task of HAR. The significant findings of this chapter are summarized below:

- A novel CNN-LSTM self-attention architecture is proposed for the purpose of HAR.
- The complexity analysis in terms of FLOPS is performed, which demonstrates that the proposed model is less complex.
- A thorough ablation study is presented to justify the model depth with respect to the trainable parameters.
- 1-D GradCAM is proposed and implemented to precisely pinpoint the features learnt by the model which are responsible for HAR.
- Comparative study shows that the F_w -score of the proposed model is better than the existing SOTA models.

Table 5.1 Performance Comparison Between Performed Works

Metrics	*Seq2Dense U-Net: Analyzing Sequential Inertial Sensor data for HAR using Dense Segmentation Model*				*An eXplainable Self Attention Based Spatial-Temporal Analysis for HAR*			
	Sanitation	*UCI-HAPT*	*UCI-HAR*	*mhealth*	*Sanitation*	*UCI-HAPT*	*UCI-HAR*	*mhealth*
Accuracy	0.9095	0.9474	0.9547	0.9011	0.9191	0.9607	0.9829	0.9044
Precision	0.9031	0.9393	0.9414	0.9121	0.9105	0.9658	0.9833	0.9143
Recall	0.9000	0.9383	0.9406	0.9011	0.9191	0.9658	0.984	0.8844
F1 score	0.9011	0.9379	0.9406	0.8928	0.9194	0.9648	0.9836	0.9016
MCC	0.8884	0.9274	0.9487	0.8950	0.9064	0.9539	0.9795	0.8783
Kappa Score	0.8883	0.9272	0.9486	0.8918	0.9063	0.9534	0.9794	0.8734

5.2 Future Scope of Research

The thesis that is being presented here cannot be expanded upon because Ph.D. work is a time-limited program. However, the study described here can open new opportunities for doing additional research studies in this field. For example, one can develop a model which can be used in real time monitoring for health care. HAR can be employed in psychological and behavioral studies to analyze patterns of behavior, emotions, and social interactions. This can lead to a better understanding of human behavior and societal dynamics. HAR can also assist in monitoring environmental conservation efforts. For example, it could help track wildlife movement patterns or illegal activities in protected areas.

Based on the studies in this thesis, a few directions such as: Enhanced Temporal Modelling, Multi-Modal Fusion, Complex Activity Recognition, Multi-Modal Fusion which can benefit for integrating data from multiple sensors, such as accelerometers, gyroscopes, and even cameras can be enlisted for the future research in this domain. Further the Adaptive Learning and Personalization and Incremental Learning algorithms can be utilized for various broad area in Real-Time Applications. Additionally, the future research can be extended for the Sparse Data Handling and Few-Shot Learning.