Chapter 6

Conclusion

Seizures commonly occur as a result of the abnormal electrical impulses delivered by damaged brain cells in epilepsy, a chronic, crippling disorder. A brain cell's unchecked electrical current spike causes seizures. Epilepsy interferes with this periodic electrical impulse pattern. Instead, electrical energy spikes between cells occur in one or more of the brain's areas. This electrical disruption causes seizures, which change awareness (including loss of consciousness), moods, emotions, and muscle actions. A system that may be adjusted to some extent to accommodate most people worldwide is essential for an automated epilepsy management system since it must be responsive whenever an episode is likely to happen. By adjusting the classifier's parameters and alerting the patient before oncoming seizures, this study's main objective is to improve the detection and prediction of ES. This study also seeks to develop techniques for removing artifacts from the recorded Electroencephalogram (EEG) signal and to create a complex feature space that captures the characteristics and diversity of EEG signals.

It is quite common for EEG signals to get affected by several types of artifacts, making extracting meaningful information from EEG signals quite challenging. These artifacts hamper the performance of end tasks like classification and prediction of ES. This work proposes a novel architecture called BS-LSTM, which has the framework of a BLSTM and the learning mechanism of a BSCN. This novel architecture is used to remove artifacts from the EEG signals of epileptic patients. The proposed methodology is efficient and performs best on five publicly available data sets. BS-LSTM is productive in removing noises like ECG, EOG, EMG, PL, and their combinations. It is observed that the performance of BLSTM is boosted when the learning is performed using the mechanism used in BSCN. The proposed technique provides consistent improvement for all the data sets. Further, experiments have proved that the proposed denoising technique enriches the quality of the EEG signals by removing the artifacts, thus boosting the efficiency of the classification or prediction performed in tasks utilizing these signals. Removing noise from the EEG signals allows for better analysis and interpretation of the underlying brain activity. Thus, denoising using the proposed BS-LSTM leads to more accurate and reliable extraction of relevant features while preserving the temporal and spatial characteristics of the EEG signal. This quality of the proposed methodology can be particularly valuable in studies aiming to detect biomarkers, assess treatment effects, or investigate subtle brain abnormalities.

This work also proposes a novel hybrid optimization technique for identifying the optimized LSTM architecture to enhance seizure detection performance. The hybrid feature set has proven to be demonstrative for expressing the non-linear characteristics of EEG signals. Then, LSTM is employed for the seizure classification. Furthermore, LSTM is optimized using BRRO since the parameters control the classifier's performance. The hybrid optimization algorithm integrates the fortification and analyzing skills of the defender and the TL, respectively. It is used to evaluate the directive to select the best parameters of LSTM while reaching faster convergence than the other standard optimization algorithms. The positive impact of the method has been observed on the classifier architecture and performance. The significance of a hybrid feature set is noted through the various EEG data sets used. Also, compact classifier architecture with decent seizure classification performance is attained. Further, various optimization methods will be explored to improve the classifier's performance.

This research proposes a novel hybrid optimization algorithm-based DL method to develop a patient-generic approach to seizure occurrence prediction through EEG information. Thus, a hybrid deep feature set is constructed by feature augmentation to mitigate the challenge of insufficient data on epilepsy patients. After that, the feature space is analyzed through SLSTM. Besides, the performance of SLSTM architecture is improved by optimizing the parameters through the underlying principle of forensic investigation involving police officers and human search and rescue operation characteristics. The optimized SLSTM is used to predict seizure events, given an SPH. Compared to conventional optimization methods, the hybrid optimization algorithm FB-SARO chooses the optimal LSTM parameters and reaches convergence faster. These characteristics enhance the classifier's performance, and its superior performance has been observed using four publicly available data sets. The prediction has been performed by utilizing seizure information from the data sets. An optimal value of SPH has been identified to warn the patients and their attendants about the upcoming seizure. Identifying the optimal SPH helps them get medical help and prepare for it in advance. Since seizure events are one of the time-critical problems in healthcare, the proposed model can achieve early prediction of a seizure event without compromising accuracy.

6.1 Future Scope

It may be worth pointing out that there is significant scope for enhancement in the proposed ES prediction and classification methods. Based on the research work presented in this thesis, the following are the future directions to explore more.

- Rehabilitation of Stroke Patients: The role of EEG in the prognosis of stroke and for the rehabilitation of stroke patients is being studied quite extensively. There are various works that discuss the importance of intelligent post-stroke rehabilitation due to the increasing stroke incidence among aging populations. For example, the authors in [207] explore the advancements in biological signal-based closed-loop rehabilitation, focusing on EMG and EEG signals. It outlines how these signals aid in understanding neuromuscular and brain function changes post-stroke and details technological interventions like intention cognitive devices and motor imagery.

  Taking this work further, advancements in technology, such as wearable devices and artificial intelligence, may lead to more personalized and effective rehabilitation interventions. Integrating multiple types of biological signals, beyond just EMG and EEG, could provide a more comprehensive understanding of neurorehabilitation processes. Additionally, there's potential for telerehabilitation solutions, enabling remote monitoring and guidance for stroke survivors. Further research may also uncover novel therapeutic targets and techniques, ultimately improving outcomes and quality of life for stroke patients.

  Challenges in the implementation of such techniques include technical complexity in integrating multiple biological signals, ensuring user acceptance and compliance, addressing data privacy concerns, managing costs and accessibility, and navigating validation and regulatory processes. Overcoming these challenges will be essential for the successful adoption and integration of these innovative solutions into clinical practice, ultimately improving outcomes for stroke survivors.

- Causal Study of Neurological Diseases: Through this research, it was observed that to understand the causes of neurological diseases, it is essential to conduct and study long-term recordings of patients. The evolution of EEG recording technology has led to the exploration of new methods for long-term ambulatory EEG monitoring. The authors in [208] examine various systems capable of recording EEGs outside clinical settings. These systems offer advantages such as sensitivity, low false detection rates, and patient tolerance, but each has its own set of pros and cons. Options like subcutaneous electrodes provide stable signals for ultra-long-term monitoring but require invasive procedures, while behind-the-ear electrodes offer discreetness but may miss certain seizure patterns. Headband-based systems are convenient but less spatially comprehensive and more susceptible to movement artifacts. This overview underscores the need for careful consideration of electrode placement and technology choice in optimizing ambulatory EEG monitoring for specific patient populations.

The future prospects of research in long-term ambulatory EEG monitoring are promising. Advancements in sensor technology may lead to more compact and efficient recording units, enhancing portability and patient comfort. Further refinement of algorithms for automatic seizure detection and forecasting could improve accuracy and reliability. Additionally, exploring novel electrode placement methods, such as subcutaneous or behind-the-ear electrodes, may offer improved signal stability and coverage. Integration with other technologies, such as machine learning and artificial intelligence, could enable real-time data analysis and personalized treatment recommendations. Overall, ongoing research in this area holds the potential to revolutionize EEG monitoring, enhancing diagnostic capabilities and patient outcomes.

Implementing long-term ambulatory EEG monitoring faces challenges, including technical complexity in sensor development, ensuring patient compliance, managing large volumes of data, maintaining signal quality, and addressing cost and regulatory concerns. Overcoming these hurdles is vital for the successful adoption of these solutions in clinical practice, requiring advances in technology, patient education, data management systems, and regulatory frameworks.

- Utilizing Explainable AI: A scope to improve the performance of the proposed model exists by utilizing explainable AI. Integrating explainable AI into the proposed model offers several benefits. It enhances interpretability, enabling clinicians to understand and trust the model's recommendations. Identifying important features guides feature selection and improves model accuracy. Explainable AI aids in error analysis, helping to refine the model and data collection processes. It promotes collaboration between clinicians and the model, allowing for feedback and corrections. Additionally, it enhances model transparency, facilitating validation and bias identification. Overall, leveraging explainable AI fosters trust, collaboration, and transparency in clinical decision-making.

- Early Detection of Alzheimer's: Alzheimer's disease (AD) is a progressive neurodegenerative disorder impacting the elderly, characterized by memory loss and cognitive decline. Works like [209] highlight research indicating that brain changes occur years before symptoms manifest. This work focuses on non-invasive biomarkers studied globally for early AD detection.

  Techniques can be developed for early detection of Alzheimer's using such biomarkers along with EEG mapping. Combining EEG with non-invasive biomarkers for Alzheimer's disease (AD) detection will enhance research by capturing real-time brain activity changes, complementing existing biomarkers, and predicting future cognitive decline. This integration can facilitate personalized diagnosis, accounting for individual brain function variations, and validate biomarker predictive value, improving early AD detection accuracy.

Implementing a combined EEG-biomarker system for Alzheimer's detection faces challenges, including data integration complexities, technical algorithm development, standardization issues, and ethical considerations. Additionally, ensuring clinical adoption and acceptance by healthcare professionals is crucial for real-world implementation.