NEURO INSIGHT

Software Design and Requirement Specification

Session: 2021–2025

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Chapter 1

Requirement Specification

The project aims to develop a desktop application for the automated diagnosis and early forecasting of epilepsy. This application is specifically designed to meet the needs of the local healthcare community in Pakistan by leveraging real-world EEG data collected from local hospitals. The application will incorporate advanced deep-learning models for the real-time analysis of EEG signals. These models will not only provide accurate diagnostic results for epilepsy but will also feature an early forecasting capability, allowing the prediction of potential epileptic episodes. This will enable healthcare professionals to take proactive measures for patient care. A key priority is the development of a user-friendly interface that allows healthcare professionals to easily input EEG data and receive both diagnostic and predictive outcomes. A **Software Requirements Specification (SRS)** is a comprehensive description of the intended purpose and environment for software under development.It serves as a communication bridge between stakeholders, developers, and testers to ensure that everyone has a clear understanding of what the software is expected to do.

- **FR - Functional Requirement:** Functional requirements specify the system's key functions, describing how it will handle inputs, process data, and produce outputs. They define essential features such as user authentication, data processing, report generation, and notifications, ensuring the system meets user needs and project objectives.
- **NR - Non-Functional Requirement:** These describe the qualities that the software must possess, such as performance, reliability, scalability, security, and usability. This section may include specifications like response times, data storage requirements, and other technical criteria.

1.1 Functional Requirements

Functional requirements define the basic behavior of the system. They specify what the system must do and how it responds to inputs related to diagnosing epilepsy and predicting seizures using EEG data. These requirements include calculations, data input, and business processes essential for the system's operation. If the functional requirements are not met, the system will not achieve its intended purpose. The following table categorizes functional requirements based on business, administrative, user, and system needs.

Category	**ID**	**Requirement Description**
3*Business Requirements	FR-01	The system must support the goal of diagnosing epilepsy using locally collected EEG signals from hospitals and provide automated diagnostic results.
	FR-02	The system must support early seizure forecasting by predicting potential epileptic episodes using real-time data to improve patient management.
	FR-03	The system must integrate authorization workflows for different user levels, allowing healthcare professionals to securely access diagnostic tools and data.
2*Administrative Functions	FR-04	The system must automatically generate reports on patient diagnoses and seizure predictions, which can be exported in various formats (PDF, CSV).
	FR-05	The system must allow for regular data updates, integrating new EEG signals from hospitals for continuous improvement and enhanced prediction accuracy.
4*User Requirements	FR-06	Healthcare professionals must be able to input EEG data into the system and receive immediate diagnostic results regarding epilepsy detection and seizure forecasting.
	FR-07	Users must be able to compare their own diagnoses with the system's predictions for educational purposes, helping improve diagnostic skills.

	FR-08	The system must allow users to visualize and review EEG signals in an easy-to-read format, with options for zooming into specific timeframes and segments.
	FR-09	Users must be able to export EEG diagnostic reports for patient records or further analysis.
4*System Requirements	FR-10	The system must support deep learning models (CNN, RNN, LSTM) to automatically extract features from EEG signals and perform accurate seizure detection and prediction.
	FR-11	The system must process large volumes of EEG data in real-time to provide timely diagnostic and predictive insights.
	FR-12	The system must perform data preprocessing steps (filtering, segmentation, normalization) on incoming EEG data to ensure clean and analyzable input for the models.
	FR-13	The system must integrate securely with local hospital systems, ensuring that only authorized healthcare professionals can access and use the EEG data and diagnostic results.

TABLE 1.1: Functional Requirements

1.2 Non-Functional Requirements

Non-functional requirements are essential for ensuring that the proposed system meets the high standards required in healthcare environments. For example, usability is critical, as it allows healthcare professionals to efficiently interact with the application, leading to quicker decision-making and improved patient outcomes. Furthermore, **reliability** guarantees that the system consistently performs as expected, which is vital in high-stakes situations where downtime can lead to severe consequences. **Performance** metrics, such as loading times and processing speed, are particularly important for maintaining the workflow in busy healthcare settings. In addition, **scalability** is necessary to accommodate future advancements in technology and increasing user demands, ensuring the system remains effective over time. Lastly, stringent **security** protocols are imperative to safeguard sensitive patient information, thereby maintaining confidentiality and compliance with healthcare regulations, which is crucial for preserving trust in the healthcare system.

Category	**ID**	**Requirement Description**
4*Performance Requirements	NFR-01	The system must be capable of processing and analyzing EEG data with a latency of less than 5 seconds to ensure timely diagnosis and prediction.
	NFR-02	The system must handle up to 100 simultaneous users without a degradation in performance or response time.
3*Usability Requirements	NFR-03	The user interface must be intuitive and easy to navigate, allowing healthcare professionals to efficiently use the system with minimal training.
	NFR-04	The system must provide help documentation and tutorials accessible within the application to assist users in utilizing all features effectively.
3*Security Requirements	NFR-05	The system must comply with HIPAA regulations to ensure the privacy and security of patient data during storage and transmission.
	NFR-06	The system must implement encryption protocols for sensitive data to protect against unauthorized access and breaches.
2*Reliability Requirements	NFR-07	The system must have an uptime of 99.9% to ensure continuous availability for healthcare professionals.
	NFR-08	The system must include a backup and recovery mechanism to restore data in the event of a system failure.
2*Scalability Requirements	NFR-09	The system must be scalable to accommodate increasing volumes of EEG data and users as more hospitals integrate with the platform.

	NFR-10	The architecture of the system must support modular updates and enhancements without significant downtime or disruptions to existing services.

Table 1.2: Non-Functional Requirements

Chapter 2

Design specification

2.1 Detailed Literature Review

The literature on epileptic seizure detection and prediction reveals a variety of approaches primarily utilizing deep learning techniques on EEG data. While several studies have achieved high accuracy rates, they often focus on individual algorithms and lack integration of real-time detection and early forecasting capabilities. Our project seeks to fill these gaps by developing a comprehensive system that enhances seizure detection and prediction, ensuring timely interventions in healthcare settings.

Serial No.	**Paper Title**	**Year**	**Description**	**Accuracy**	**Shortcomings Compared to Our Idea**
1 [11]	Epileptic Seizure Detection Using CNN-LSTM Networks on EEG Data	2023	This study used CNN to detect seizures from EEG data.	97.9%, Sensitivity: 97.3%	Focused solely on CNN, no early forecasting, limited to static data.
2 [7]	Real-Time Seizure Prediction Using Long Short-Term Memory (LSTM) Networks	2023	Implemented LSTM for real-time seizure prediction using historical EEG data.	95.8%, FPR: 0.23/h	Limited to LSTM, no combination with other models, no real-time detection.

3 [5]	Multi-Channel EEG-Based Epileptic Seizure Detection Using Deep Learning	2021	Used a deep learning model on multi-channel EEG data for seizure detection.	92%	No focus on real-time data collection or early forecasting.
4 [13]	Automated Seizure Detection Using Wavelet Transform and Deep Neural Networks	2022	Combined wavelet transform with deep neural networks for automated seizure detection.	89%	No real-time detection or early forecasting, specific to wavelet transform.
5 [10]	Seizure Prediction Using RNN with EEG Data	2022	Implemented RNN for predicting seizures based on EEG data.	87%	Only uses RNN, lacks integration with other models, no real-time application.
6 [6]	Epileptic Seizure Detection Using a Hybrid Deep Learning Model	2022	Developed a hybrid model combining CNN and LSTM for improved seizure detection.	93%	Does not include real-time data collection or early forecasting capabilities.
7 [8]	Real-Time Epileptic Seizure Prediction Using Deep Learning Techniques	2023	Utilized deep learning techniques for real-time seizure prediction.	91%	Focus on prediction, lacks comprehensive real-time detection.

8 [12]	Early Prediction of Seizures Using Deep Learning and EEG Data	2023	Explored early prediction of seizures using deep learning models and EEG data.	90%	Limited to early prediction, lacks real-time detection and integrated system.
9 [9]	Advanced Machine Learning Techniques for Real-Time Seizure Detection and Prediction	2023	Examined advanced ML techniques for both real-time detection and prediction of seizures.	92%	General overview, lacks detailed implementation and specific model comparison.

Table 2.1: Related System Analysis

2.2 Related Work

Related System	**Description**	**Limitations**	**Proposed Project Solution**
Epsy [1]	Epsy is a digital health platform that helps people with epilepsy track and manage their seizures, medications, and overall health.	Requires manual input of seizure data, may not detect seizures in real-time.	Our system will integrate real-time data collection and automatic detection, reducing reliance on manual input and enhancing real-time detection capabilities.
Seizure Tracker [4]	Seizure Tracker is a simple and easy-to-use app that helps people with epilepsy monitor their seizures and identify patterns.	Does not provide real-time seizure detection or alerts.	Implement real-time detection features to provide immediate seizure monitoring.

My Seizure Diary [2]	My Seizure Diary is a comprehensive digital diary that helps people with epilepsy track and manage their seizures.	Does not provide real-time seizure detection or alerts.	Add real-time detection capabilities to enhance user experience.
Open Seizure Detector [3]	OpenSeizureDetector is an open-source app that uses machine learning algorithms to detect seizures in real-time.	Requires manual input of seizure data, may not be accurate in detecting seizures.	Our system will enhance the accuracy of detection algorithms and minimize manual data input through better automated systems.

TABLE 2.2: Related System Analysis

2.3 Proposed Methodology

The proposed methodology/system for epilepsy management involves a systematic approach to leverage data-driven techniques for accurate diagnosis, effective treatment, and improved patient care. Below is the comprehensive methodology for the project:

Model Preparation:

1. **Data Acquisition:**
    - Collaborate with local hospitals to gather extensive EEG recordings from patients diagnosed with epilepsy.
    - Engage specialist doctors to assist in annotating the data, ensuring accurate labeling of the preictal, ictal, postictal, and interictal phases of epileptic seizures.
    - Ensure compliance with ethical standards and obtain necessary permissions for data acquisition.
2. **Data Preprocessing:**
    EEG data is often noisy and contains artifacts that can interfere with accurate analysis. Various signal processing techniques will be employed to preprocess the data:
    - **Filtering**: Remove noise and artifacts using band-pass filters.

- **Segmentation**: Divide the continuous EEG recordings into smaller, manageable segments.
- **Normalization**: Standardize the EEG signals to have zero mean and unit variance.

3. **Feature Extraction:**
   To capture the intricate patterns in EEG signals associated with epileptic seizures, advanced feature extraction techniques will be used:

   - **Time-Domain Features:** Extract statistical features such as mean, variance, and standard deviation.
   - **Frequency-Domain Features:** Utilize Fast Fourier Transform (FFT) and Short-Time Fourier Transform (STFT) to analyze the frequency components of the EEG signals.
   - **Time-Frequency Features:** Apply Wavelet Transform to capture both time and frequency information.

4. **Model Development:**
   We will develop and train deep learning models to automate the feature extraction and classification processes:

   - **Convolutional Neural Networks (CNNs)**: Use CNNs to automatically extract spatial features from the EEG signals.
   - **Recurrent Neural Networks (RNNs)**: Employ RNNs to capture the temporal dependencies in the EEG data.
   - **Long Short-Term Memory Networks (LSTMs)**: Utilize LSTMs to handle long-term dependencies and improve seizure prediction accuracy.

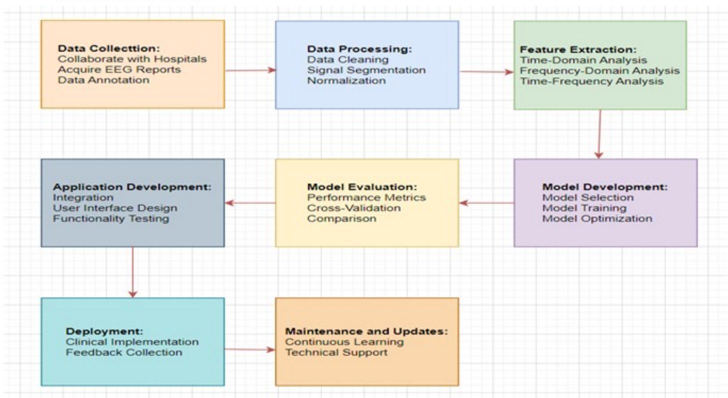

FIGURE 2.1: Steps of Proposed Methodology

5. **Model Training and Validation:** The annotated EEG data will be split into training, validation, and test sets.

    - Deep learning models will be trained using the training set and validated on the validation set to fine-tune the model parameters.
    - The test set will be used to evaluate the final model performance.
    - Metrics such as accuracy, sensitivity, specificity, and F1-score will be used to assess the model's effectiveness in detecting and predicting epileptic seizures.

6. **Deployment and Integration:**

    - The trained model will be integrated into a user-friendly interface or decision support system for clinical use.
    - Once validated, the application will be deployed for use in local hospitals.
    - Regular updates and maintenance will be provided to incorporate new data, refine the models, and ensure the application remains effective and up-to-date.

7. **Continuous Monitoring and Improvement:**

    - Monitor the deployed model's performance in real-world clinical settings and gather feedback from clinicians and patients.
    - Incorporate new EEG and clinical data to update the model periodically and adapt to changes in patient populations and clinical practices.
    - Implement mechanisms for model retraining and version control to maintain accuracy and relevance over time.

Flexibility in Future Work In future iterations, the methodology may be adjusted to employ any one of the models (CNN, RNN, LSTM) or a combination of these, based on the evolving needs and advancements in the fie.

2.4 Data collection techniques

To build an effective EEG dataset for epilepsy seizure detection, our primary source of data will be the neurology department at Shalamar Hospital in Lahore. This approach ensures high-quality, clinically relevant data for our project. The detailed data gathering strategy includes:
Clinical Collaborations

1. **Shalamar Hospital:**

- **Objective:** Partner with the neurology department to collect EEG recordings from patients diagnosed with epilepsy.
- **Rationale:** Shalamar Hospital provides access to a diverse set of EEG signals from a variety of patients with different types of epilepsy and seizure patterns. Collaborating closely with experienced neurologists guarantees the medical accuracy and relevance of the collected data.
- **Process:**
  - **Patient Recruitment:** Work with neurologists to identify and recruit patients diagnosed with epilepsy who are willing to participate in the study.
  - **EEG Recording:** Collect EEG recordings during routine clinical visits and specific epilepsy monitoring sessions.
  - **Data Labeling:** Annotate the EEG recordings with relevant clinical information, including the onset and duration of seizures, type of seizure, and patient demographic details.

2. **Potential Expansion to Other Hospitals:**
   Additional Data Sources:

   - Depending on the progress and requirements of the project, we may visit other hospitals in Lahore to collect additional EEG data.This will help in creating a more comprehensive and diverse dataset.Enhancing the robustness of the dataset.

3. **Data Management and Security:**

   - **Data Labeling:** All EEG recordings will be meticulously labeled with accurate annotations to ensure clarity and usability in the machine learning model training process.
   - **Data Storage:** Implement secure data storage solutions with encryption to protect patient confidentiality and prevent unauthorized access.
   - **Ethical Compliance:** Obtain informed consent from all participating patients and ensure adherence to ethical standards and regulations in data collection and handling.

4. **Quality Assurance:**

   - **Continuous Monitoring:** Regularly review the collected data to maintain high standards of quality and consistency.

- **Collaboration with Experts:** Engage with neurologists and data scientists to validate the accuracy and relevance of the data.
- **Feedback Loop:** Establish a feedback loop with the clinical team at Shalamar Hospital to address any issues or improvements in the data collection process.

By focusing primarily on data from Shalamar Hospital and potentially expanding to other hospitals, we ensure that our dataset is both high-quality and clinically relevant, providing a solid foundation for developing effective epilepsy seizure prediction and detection models. This approach also streamlines the data collection process and facilitates close collaboration with medical experts, enhancing the overall project outcomes.

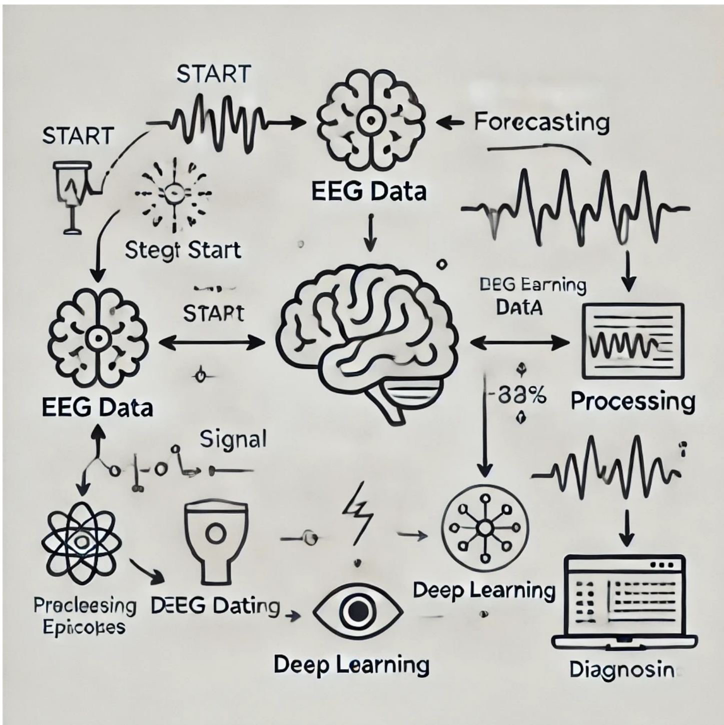

Figure 2.2: Flow Chart Diagram

2.5 Experimental Design

The experimental design for our epilepsy diagnosis system focuses on detecting epilepsy, identifying its specific type, and forecasting potential seizures using EEG signals. The system is primarily intended for use by young doctors, offering them a platform to compare their diagnoses with the system's output for educational purposes. The experiment will involve EEG data, either collected from hospitals or using benchmark datasets. The methodology consists of several stages: **gathering, preparation, transformation, selection, fitting, and assessment**.

2.5.1 Data Collection:

The EEG data will be gathered from local hospitals in Lahore, such as Shalimar and Mayo, though obtaining this data has been challenging. We are still working to establish contacts with hospitals for real patient data collection. Meanwhile, we explored benchmark datasets available online, which offer similar EEG data, allowing us to proceed with testing and validating the models.

2.5.2 Data Input:

The system is designed to accept EEG data either through a USB (from stored EEG files) or in real-time using EEG acquisition hardware. The input EEG files will likely be in formats such as **.edf** or **.eeg**. Data from multiple channels (such as 19-channel EEG recordings) will be used to capture detailed brainwave activity, which will be processed further for diagnosis.

2.5.3 Feature Extraction:

Relevant features from the preprocessed EEG data will be extracted to highlight patterns linked to epileptic activity. These features will include time-domain and frequency-domain characteristics, such as power spectral density and signal amplitude.

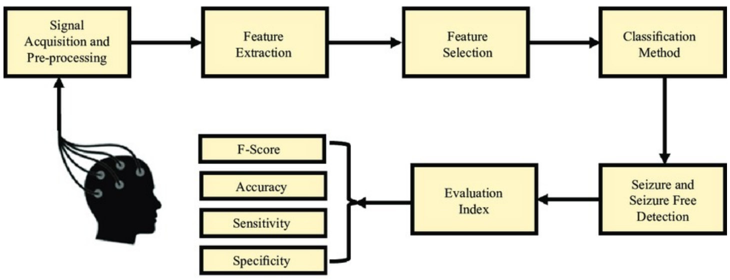

Figure 2.3: Diagrammatic Representation of Experimental Design

2.5.4 Model Selection:

Several deep learning models will be used for classification and forecasting:

- **LSTM (Long Short-Term Memory):** To forecast epileptic seizures based on sequential EEG data.
- **GNN (Graph Neural Networks):** To capture spatial relationships between EEG electrodes and detect epilepsy types.
- **DCNN (Deep Convolutional Neural Networks):** For feature extraction and classification of epilepsy types.

2.5.5 Training and Evaluation:

The dataset will be split into training, validation, and testing sets to evaluate model performance. Cross-validation will be employed to minimize overfitting, and hyperparameter tuning will optimize the model's accuracy. Metrics such as accuracy, precision, recall, and F1-score will be used to assess the models' ability to diagnose epilepsy and predict seizures.

2.5.6 Real-World Validation:

Once trained, the models will be validated using a separate dataset with unseen EEG data to assess their real-world applicability. This phase is crucial for testing the system's reliability in diagnosing different types of epilepsy and forecasting seizures.

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