Sleep Disorder Detection from Polysomnography data and lifestyle changes recommendations for actionable insights

Group No: 48

Project Overview

Problem Statement

Sleep disorders such as insomnia, apnea, and restless leg syndrome frequently go undiagnosed in India due to limited awareness, and restricted access to clinical facilities. Existing diagnostic methods are often inaccessible or difficult for patients to understand, creating a gap between medical expertise and public usability. There is a growing need for an accessible, transparent, and interpretable system that can screen sleep disorders and guide individuals with clear, personalized insights. This project addresses this need by developing a web-based framework that combines PSG-based analysis, explainable AI, and interactive recommendations to support both clinicians and patients.

Objectives :

- To develop a web-based framework that performs automated sleep disorder screening using Polysomnography (PSG) data and transformer-based sleep stage classification.
- To extract relevant sleep metrics from classified sleep stages and use them to identify potential disorders such as insomnia, apnea, and restless leg syndrome.
- To integrate Explainable AI methods, including visual reports and saliency-based interpretability, to support clinicians with transparent and trustworthy insights.
- To create an interactive platform that delivers clear medical explanations, personalized lifestyle recommendations, and remedy suggestions through a multi-agent RAG-based system.
- To enhance public awareness, reduce social stigma, and improve early detection of sleep disorders, especially in communities with limited clinical access.

Methodology :

1. **Data Harmonisation**
   Multiple Polysomnography datasets were merged by identifying shared channels and aligning them to a common structure, enabling consistent downstream processing.

2. **System Architecture Design**
   A high-level system architecture was created to define modules, data flow, and integration points for preprocessing, model training, inference, and web deployment.

3. **Data Preprocessing**
   The signals were cleaned through artifact removal and uniformly resampled to 128 Hz to ensure reliable and standardised inputs for the model.

4. **Feature Extraction**
   Model-ready features were extracted from the processed signals to capture relevant physiological patterns essential for sleep stage classification and disorder inference.

5. **Transformer Architecture Design**
   A transformer-based model architecture was designed by combining insights from multiple datasets and tailoring the network to effectively capture temporal dependencies in PSG signals.

6. **Model Training**
   The transformer model was trained on harmonised and preprocessed data to achieve accurate sleep stage predictions and downstream disorder detection.

7. **Inference Generation with XAI**
   Explainable AI techniques were integrated to generate clinical interpretations, including saliency visualisations and metric-based reports that reveal the model's decision process.

8. **Agentic AI with RAG**
   A multi-agent Retrieval-Augmented Generation system was built to handle medical queries, generate evidence-grounded explanations, and provide personalized lifestyle recommendations.

9. **Web App Development**
   Finally, the framework was deployed as a cloud-based web application, enabling clinicians and patients to interact with the system through an intuitive and accessible interface.

Tools / Technologies Used:

Programming & Deep Learning: Python, PyTorch for model development and training

Signal Processing: NumPy, SciPy, MNE for Polysomnography signal handling and preprocessing

Version Control: Git, GitHub for collaboration and code management

Explainable AI (XAI): Captum, SHAP, gradient-based saliency methods for interpretability

Visualization & Analysis: Matplotlib, Seaborn, Plotly for performance metrics and signal visualisation

Expected Outcomes:

1. **Accurate Sleep Disorder Screening:**
   The system successfully identifies potential sleep disorders by analysing PSG signals, sleep stages, and extracted metrics.

2. **Transparent Clinical Interpretability:**
   Explainable AI visualisations and reports provide clinicians with clear insight into model reasoning, reducing the black-box barrier.

3. **Enhanced Patient Understanding:**
   Users receive simple explanations of their sleep patterns along with personalized lifestyle recommendations, improving health awareness and engagement.

4. **Interactive AI-Powered Support:**
   The RAG-enabled multi-agent system delivers medically grounded answers, remedies, and educational insights tailored to the user.