Sleep States Prediction Using Large Language Models

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Introduction

Sleep constitutes a fundamental physiological process with profound influence on health and cognitive performance. Traditional polysomnography (PSG) requires specialized facilities and trained technicians, rendering it financially prohibitive and geographically inaccessible for widespread clinical applications.

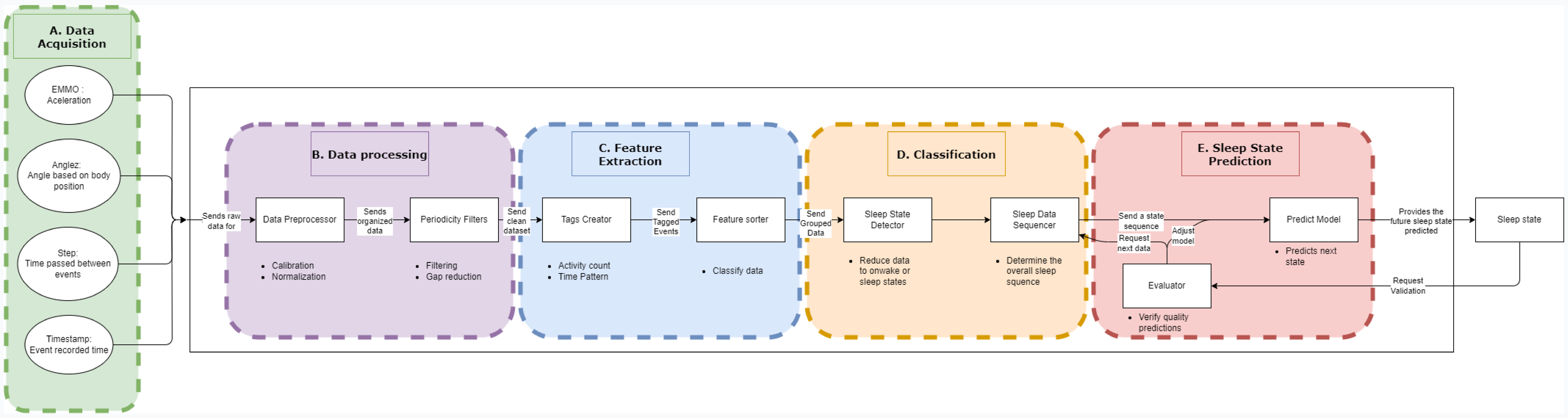
Contemporary advances in wearable sensor technology have facilitated the utilization of accelerometric devices as non-invasive alternatives. Previous solutions include Cole-Kripke (1992), Sadeh (1994), and OPAL algorithms, each with specific limitations in accuracy and adaptability.

Research Goal

Research Question: How can we systematically understand sleep states classification and prediction by integrating traditional actigraphic algorithms with Large Language Models from a comprehensive systems perspective?

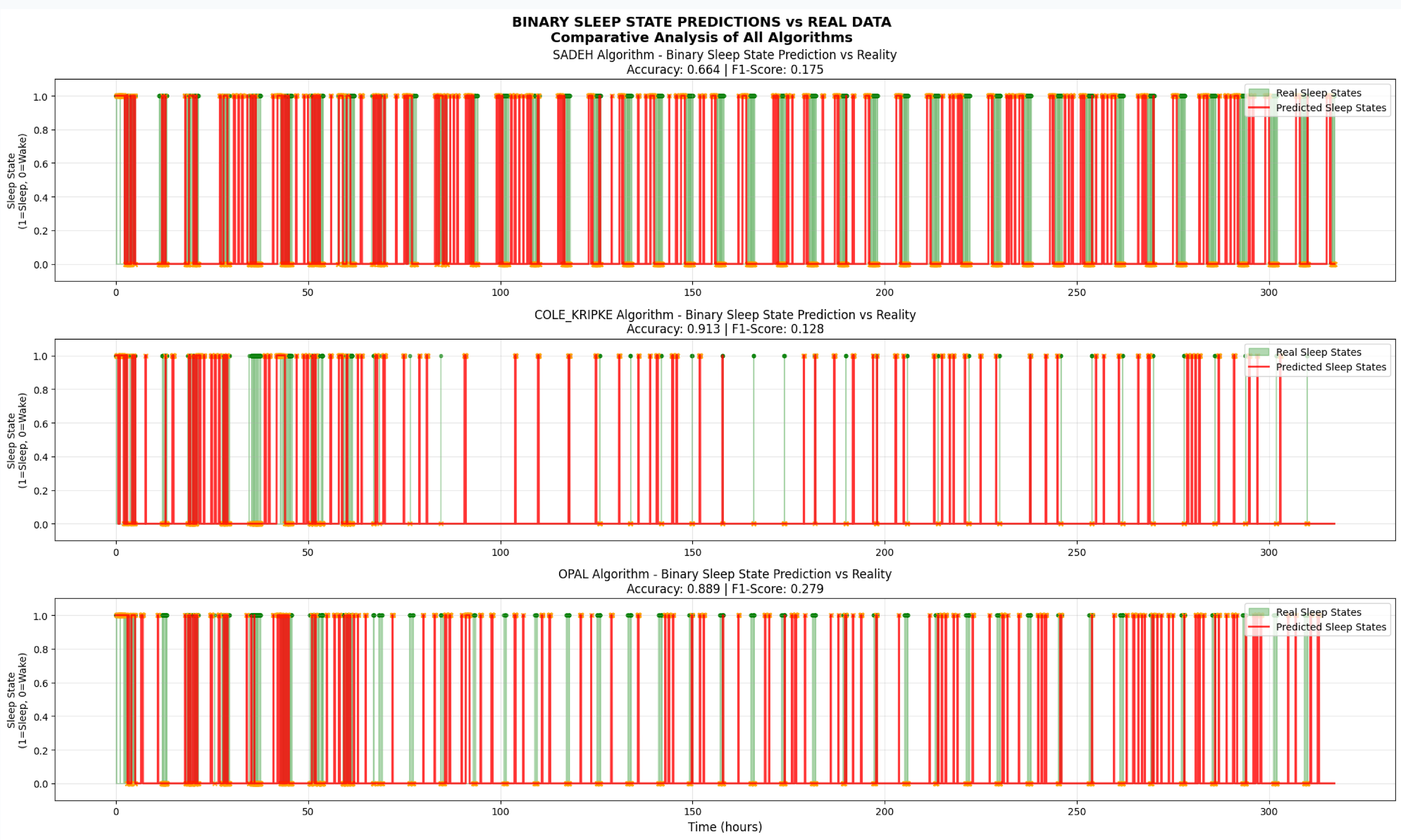
Expected Product: A systematic framework that provides comprehensive understanding of sleep state classification through traditional algorithms (Cole-Kripke, Sadeh, OPAL) and enhanced prediction capabilities using LLM integration, demonstrating the complete pipeline from a systems engineering approach.

Proposed Solution - System Architecture



Our solution implements a five-module pipeline: (1) Data Acquisition from wearable accelerometers, (2) Signal Processing with calibration and normalization, (3) Feature Extraction calculating activity counts, (4) Classification using traditional algorithms (Cole-Kripke, Sadeh, OPAL), and (5) LLM Enhancement via Amazon Chronos transformer. The key innovation integrates pretrained time series foundation models to capture long-range temporal dependencies in sleep-wake cycles, providing probabilistic forecasts with uncertainty quantification.

Results & Performance Analysis



Algorithm	Accuracy	F1-Score	Performance
Cole-Kripke + LLM	91.3%	12.8%	Best overall accuracy
OPAL + LLM	88.9%	27.9%	Best sleep detection
Sadeh + LLM	66.4%	17.5%	Enhanced fragmentation

Amazon Chronos transformer demonstrated superior capability in capturing complex temporal patterns across 300 hours of sleep data. The LLM enhancement provided probabilistic forecasts with uncertainty quantification, significantly improving prediction reliability.

Conclusion & Future Work

Our hybrid approach successfully achieved the research goal by integrating traditional actigraphy with Large Language Models for enhanced sleep state prediction.

Key Achievements:

- Cole-Kripke + LLM: 91.3% accuracy
- Real-time monitoring capabilities
- Uncertainty quantification
- Modular architecture design

Future Directions:

- Personalized algorithm calibration
- Wearable device integration
- Clinical deployment optimization

Bibliography

- Ansari, A.F. et al. (2024). "Chronos: Learning the Language of Time Series." Amazon Science.
- Cole, R.J. et al. (1992). "Automatic sleep/wake identification from wrist activity." Sleep, 15(5).
- Sadeh, A. et al. (1994). "Activity-based assessment of sleep-wake patterns." Sleep, 17(3).