Erdos Institute Data Science Boot Camp (Summer: May-2024 Cohort)
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Executive Summary

Project Title: Advancing Cardiac Diagnostics: Deep Learning Approaches for ECG-Based Heart Condition Analysis and Reconstruction

Cardiovascular diseases are a leading cause of death globally, and improving diagnostic tools is vital for early detection and treatment. This project leverages machine learning to enhance cardiac diagnostics, focusing on irregular heartbeat classification and activation map reconstruction using ECG signals.

Background and Data Set:

We developed machine learning models to improve heart condition diagnosis, using data from the ECG Heartbeat Categorization Dataset on Kaggle for classification tasks, and simulated intracardiac voltage recordings from Landajuela's cardiac-ml repos for reconstruction tasks.

Data Preprocessing:

Two preprocessing approaches were employed: normalizing and segmenting raw ECG signals to retain their temporal information, and transforming these signals into Gramian Angular Fields (GAF) for image-based analysis using CNNs. The first approach allows us to effectively capture the temporal dynamics of the ECG signals while the second leverages the power of advanced CNN architectures and transfer learning with well-established models, thereby enhancing the overall effectiveness of the analysis.

Choice of ML Model:

- Objective 1: Both XGBoost and CNNs were used for normal vs. irregular heartbeat classification, combining time-series and image analysis for robust results.
- Objective 2: The same dual approach was applied for multiclass heartbeat classification, ensuring accurate arrhythmia identification.
- Objective 3: A 1D CNN was used to reconstruct activation maps, capturing temporal patterns with high fidelity.
- Objective 4: The 1D CNN was extended with LSTM layers to improve transmembrane potential reconstruction, highlighting the need for HPC resources for further development.

Our models show promising results both for the classification task (~98% accuracy, ~5% False Negative rate) and for the activation map reconstruction (~12.06 msec error over all recording points).

Future Directions:

Moving forward, leveraging HPC is essential, particularly for the reconstruction tasks, to build complex models that deepen insights into heart activity. Additionally, exploring Vision Transformers (ViTs) for analyzing GAF images could enhance classification accuracy and predictive modeling, pushing the boundaries of ECG analysis in healthcare.

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