A Transformer-Based Approach to Diagnose Amyotrophic Lateral Sclerosis via Electroencephalogram Analysis

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Agenda

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2. Literature Review
3. Methodology
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    - Data Preprocessing
    - Model Architecture
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Introduction

- ALS impairs nerve cell function in the central nervous system
- Difficult to identify in its early stages since an exact cause is elusive
- Total diagnostic time often ranges from 8 to 15 months [1]
- Leads to significant muscle weakness, atrophy, and, ultimately, complete loss of voluntary movement
- Challenges in diagnosing ALS are compounded by the limitations of current diagnostic practices

[1] S. Paganoni, E. Macklin, A. Lee, A. Murphy, J. Chang, A. Zipf, M. Cudkowicz, and N. Atassi, "Diagnostic timelines and delays in diagnosing amyotrophic lateral sclerosis (ALS)," Amyotrophic Lateral Sclerosis & Frontotemporal Degeneration, vol. 15, no. 5-6, pp. 453-456, September 2014, doi: 10.3109/21678421.2014.903974.

Literature Review

- Image Classification
  - Kushol et al. [2] - 88.0% accuracy, 0.900 F1-score
- Audio Transformers
  - Kurmi et al. [3] - 84.2% accuracy, 77.8% sensitivity, 90% specificity
- EEG Analysis
  - Zhao and He [4] - 92% accuracy (Alzheimer's); Oh et al. [5] - 88.25% accuracy (Parkinson's)

[2] R. Kushol, C. Luk, A. Dey, M. Benatar, H. Briemberg, A. Dionne, N. Dupr´e, R. Frayne, A. Genge, S. Gibson, S. Graham, L. Korngut, P. Seres, R. Welsh, A. Wilman, L. Zinman, S. Kalra, and Y. Yang, "SF2Former: Amyotrophic lateral sclerosis identification from multi-center MRI data using spatial and frequency fusion transformer," Computerized Medical Imaging and Graphics, vol. 108, 2023, doi: https://doi.org/10.1016/j.compmedimag.2023.102279.

[3] O. P. Kurmi, M. Gyanchandani, N. Khare and A. Pillania, "Classification of Amyotrophic Lateral Sclerosis Patients using speech signals," 2023 Third International Conference on Secure Cyber Computing and Communication (ICSCCC), Jalandhar, India, 2023, pp. 172-177, doi: 10.1109/ICSCCC58608.2023.10176797.

[4] Y. Zhao and L. He, "Deep Learning in the EEG diagnosis of Alzheimers disease," Computer Vision - ACCV 2014 Workshops. ACCV 2014. Lecture Notes in Computer Science, vol. 9008, pp. 340-353, 2015, January 2015, doi: https://doi.org/10.1007/978-3-319-16628-5 25.

[5] S. Oh, Y. Hagiwara, U. Raghavendra, R. Yuvaraj, N. Arunkumar, M. Murugappan, and U. Rajendra Acharya, "A deep learning approach for Parkinson's disease diagnosis from EEG signals," Neural Computing and Applications, vol. 32, pp. 10927–10933, 2020, doi: https://doi.org/10.1007/s00521-018-3689-5.

Dataset

- Model trained on the EEGET-ALS dataset
- Contains EEG recordings using Emotiv EPOC Flex Device
- 176 subjects, with both ALS patients and healthy individuals
- Each recording session lasted approximately 2 minutes at a sampling frequency of 128 Hz
- Dataset comprises 1,989 EDF files across 32 channels

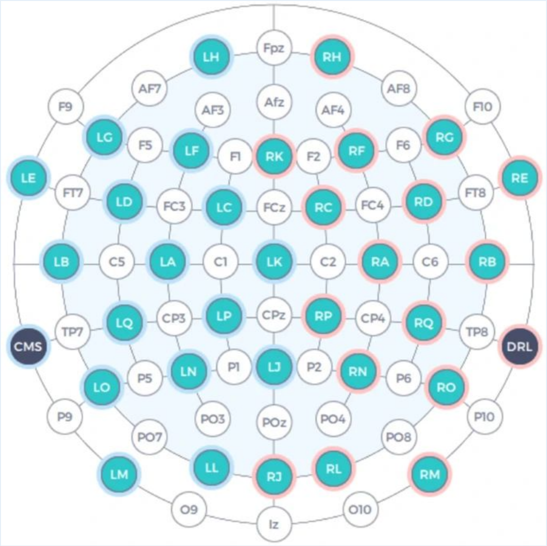

Fig. 1: EEG electrodes position with 10-10 standard [6]

[6] T. Ngo, H. Kieu, M. Nguyen, T. Nguyen, V. Can, B. Nguyen, and T. Le, “An EEG & eye-tracking dataset of ALS patients & healthy people during eye-tracking-based spelling system usage,” Scientific Data, 2024, doi: https://doi.org/10.1038/s41597-024-03501-y.

Data Preprocessing

- Each recording was adjusted to 120 seconds or a length of 15,360 given the 128 Hz sampling rate
- Labels: 0 - healthy individuals, 1 - ALS patients
- EDF files located in a folder beginning with ‘id’ contain data from healthy patient
- Files located in a folder beginning with ‘ALS’ contain data from ALS patients
- Converted to a tf.data.Dataset object using the from_tensor_slices method

Model Architecture

- Transformer-based neural network designed for binary classification
- Accepts input sequences of shape (32, 120 × 128)
- 3 layers each featuring multi-head attention
- ReLU activations with 64, 128, and 256 neurons
- Flattens before batch normalization
- Sigmoid activation for binary classification

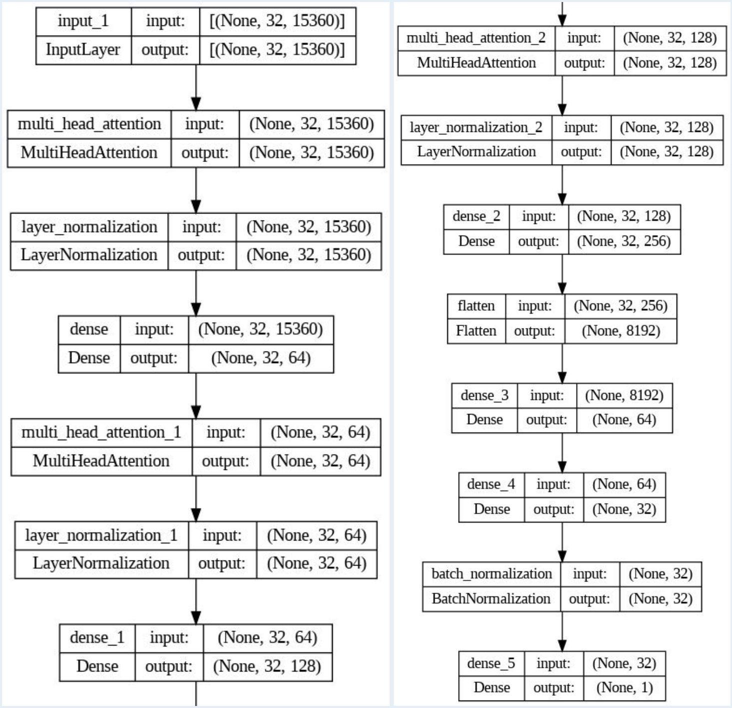

Fig. 2: Summary of Transformer model architecture

Training

- Random train-validation-test split of 70%-15%-15%
- Batch size of 16
- A100 Google Colaboratory GPU instance
- 403.88 seconds over the course of 70 epochs
- Compiled with the Adam optimizer at a learning rate of 10^{-4}
- Binary cross-entropy loss function

Results

- Five performance metrics: accuracy, loss, AUC, precision, and recall

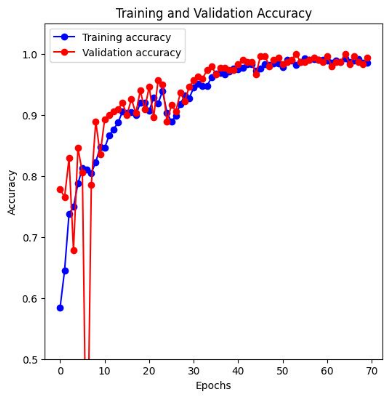

Fig. 3: Training and validation accuracy plot

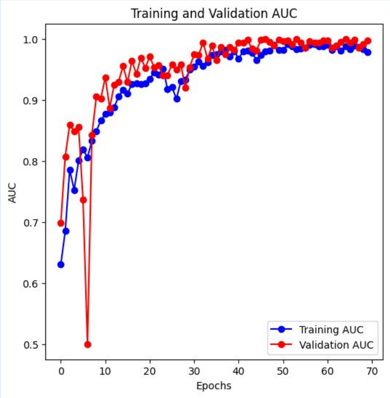

Fig. 4: Training and validation AUC plot

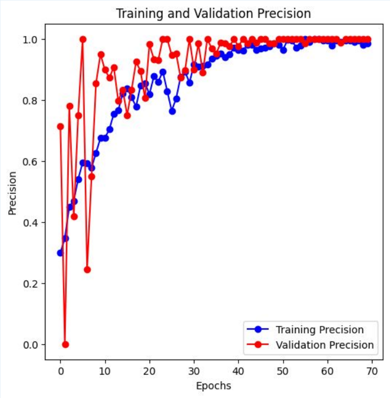

Fig. 5: Training and validation precision plot

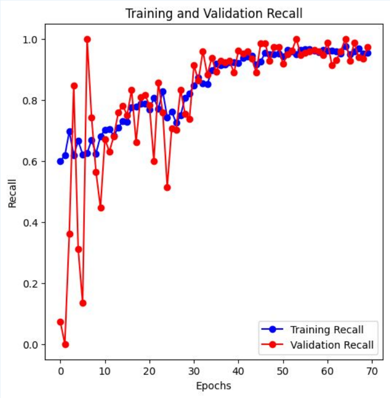

Fig. 6: Training and validation recall plot

Results (cont.)

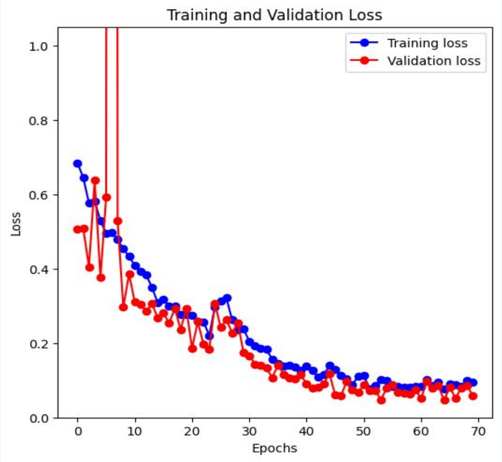

Fig. 7: Training and validation loss plot

TABLE I: Model Performance Metrics

Metric	Training	Validation	Testing
Accuracy	98.49%	99.33%	99.33%
Loss	0.0954	0.0581	0.0630
AUC	0.9787	0.9974	0.9963
Precision	98.48%	100.0%	100.0%
Recall	95.31%	97.33%	96.36%

Conclusion

- Overcomes the significant delay in reaching a definitive diagnosis
    - Two-minute recording vs. 8-15 months
- Achieves remarkable accuracy compared to other models
    - 99.33% accuracy in testing and validation
- Potential to be a valuable tool in clinical settings
- Enables earlier intervention

Future Work

- Incorporate more diverse EEG recordings from a larger and more varied cohort of ALS patients
- Use additional features such as eye-tracking data to further improve diagnostic accuracy
- User-friendly software application that integrates the model
- Promise of improved outcomes and enhanced quality of care for ALS patients through a two-minute recording

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Questions?

Check out my code:

https://github.com/sjain2025/EEG-ALS-Diagnosis