BrainGuard: MRI-Based Alzheimer Detection

Technical Report

1. Problem Framing

Alzheimer disease is a progressive neurodegenerative disorder. Early detection is critical for intervention. This project addresses automated classification of MRI scans into four dementia severity levels: Non-Demented, Very Mild, Mild, and Moderate Dementia.

Objective:

Develop and evaluate deep learning models that accurately classify brain MRI images into dementia severity classes with clinical interpretability via Grad-CAM explainability.

2. Methods

Data Preprocessing:

MRI images undergo grayscale conversion, resizing to 224224 pixels, and normalization using ImageNet statistics (mean=0.485, std=0.229). For 3D NIfTI data, the middle axial slice is extracted. Data augmentation includes rotation (15), horizontal flips, and color jitter.

Model Architectures:

ResNet50 Transfer Learning: Leverages ImageNet-pretrained weights with the first convolutional layer adapted for single-channel input. Custom CNN: A 4-block architecture (3264128256 filters) with batch normalization, ReLU activations, max-pooling, and dropout (rate=0.5). Both models employ Grad-CAM for class activation mapping.

Training Configuration:

Models use CrossEntropyLoss with Adam optimizer (lr=1e-3, weight_decay=1e-4) and ReduceLROnPlateau scheduler. Training spans up to 50 epochs with batch size 32. Validation monitors accuracy and loss to prevent overfitting.

3. Evaluation

Metrics:

Accuracy, Precision, Recall, and F1-score are computed with weighted averages for class imbalance. A confusion matrix details per-class patterns.

Validation Strategy:

Data is partitioned into training, validation, and test sets with stratified sampling. Final test-set evaluation measures real-world performance without data leakage.

Explainability:

Grad-CAM generates saliency maps highlighting brain regions influential in predictions, facilitating clinical interpretability and verification that models leverage anatomically relevant dementia biomarkers.

Limitations & Future Work:

Current limitations: single-slice 2D processing (losing 3D context), dataset bias toward specific scanners, lack of clinical validation. Future work should incorporate 3D volumetric models and prospective clinical validation. This system is for research and education only.