

Project Title:

Brain Tumor Classification and Segmentation using Ensemble Attention and Explainable AI

Problem Statement:

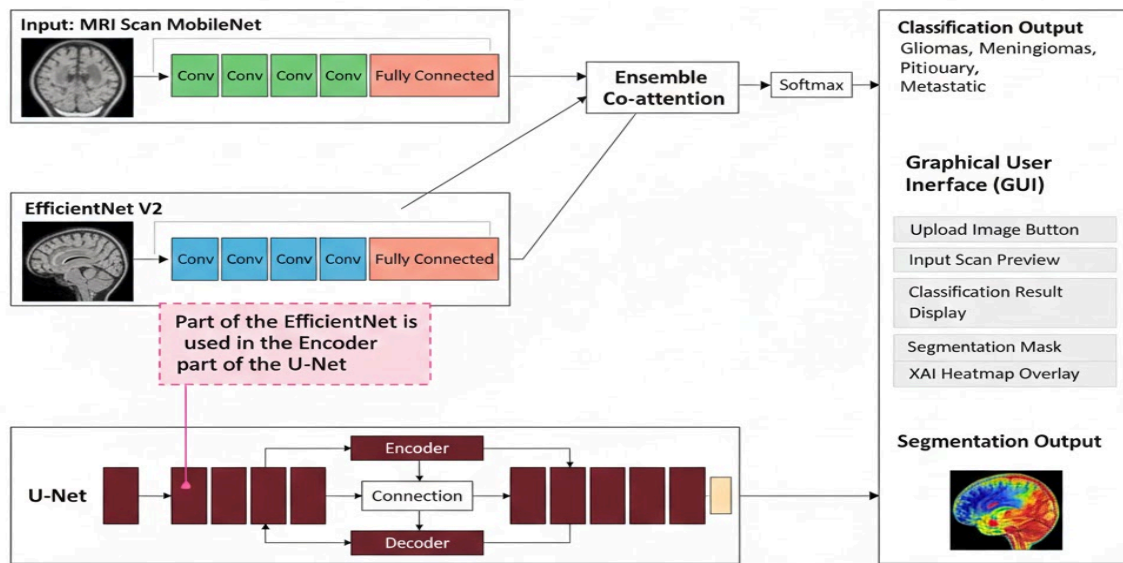
The diagnosis of brain tumors from Magnetic Resonance Imaging (MRI) is a complex, time-consuming task for radiologists, often leading to potential delays or diagnostic inconsistencies due to the subtle visual heterogeneity and varied morphology of tumors (e.g., Meningioma, Glioma, Pituitary). The critical gap is the lack of automated systems that are not only highly accurate in both defining tumor boundaries (segmentation) and identifying the tumor type (classification), but also transparent. Without **Explainable AI (XAI)**, clinicians cannot trust the "black-box" predictions of deep learning models, limiting their adoption in high-stakes medical settings.

Proposed Concept

This project proposes a unified, multi-task deep learning architecture that leverages **MobileNet** and **EfficientNet** as efficient, pre-trained backbones (encoders) for feature extraction. The architecture is composed of these efficient CNNs combined with a specialized **U-Net** structure for segmentation.

The core approach involves:

1. **Multi-Task Learning:** Utilizing parallel encoders (MobileNet and EfficientNet) with a shared feature fusion block to learn general, robust image features for both tasks, improving efficiency and generalization.
2. **Ensemble Attention and Backbone Integration:** The system will use an *ensemble* approach by integrating and fusing features extracted from two distinct, efficient backbone architectures (**MobileNet** and **EfficientNet**). Multiple, diverse attention mechanisms (e.g., Spatial and Channel Attention Modules) will be integrated into the feature fusion step to dynamically recalibrate and highlight tumor-specific features crucial for accurate prediction.
3. **Explainable AI Integration:** Post-hoc XAI techniques, specifically **Gradient-weighted Class Activation Mapping (Grad-CAM)**, will be applied to the trained model. This generates visual heatmaps overlaid on the input MRI, highlighting the exact image regions (pixels) that contributed most strongly to the model's classification decision.



Methodology

- Data Acquisition and Preparation:** Source and organize a public or private multi-class brain tumor MRI dataset. Apply standard preprocessing steps including image normalization, intensity standardization, and data augmentation to improve model robustness.
- Architecture Implementation:** Develop the custom multi-task model leveraging **transfer learning** by initializing two parallel encoders based on **MobileNet** and **EfficientNet** architectures. Design a feature fusion layer with the ensemble attention mechanism, feeding into the **U-Net** based segmentation decoder and the classification head. Implement a combined loss function that optimizes both segmentation (e.g., Dice Loss) and classification (e.g., Cross-Entropy Loss).
- Training and Interpretation:** Train the model end-to-end. Implement the Grad-CAM technique to visualize and interpret the model's reasoning on test cases, validating that the network is focusing on medically relevant features (the tumor region).
- Performance Evaluation:** Evaluate the segmentation branch using metrics like Dice Coefficient and IoU, and the classification branch using Accuracy, Precision, Recall, and F1-Score.

Expected Outcome / Applications

Expected Outcome: A single, high-performing deep learning model that can accurately localize (segment) and classify (type) brain tumors from MRI scans, providing a reliable, visually explainable prediction.

Applications:

- **Clinical Decision Support:** Assisting radiologists by providing a quick, pre-segmented, and pre-classified result, serving as a second opinion system.
- **Surgical Planning:** Providing precise segmentation masks that can be used for pre-operative tumor volume and location mapping.
- **Trust and Validation:** The XAI heatmaps enable human inspection, increasing clinician trust in AI-driven diagnostics.

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