Project Proposal: Deep Learning-Based Segmentation and Multi-Class Classification of Brain Tumors Using Multi-Institutional MRI Datasets

ABSTRACT

Brain tumors differ in origin and prognosis, from benign tumors to aggressive gliomas and metastatic lesions. Accurate segmentation and classification are essential for precise diagnosis and effective treatment planning. This project introduces a deep learning pipeline that first segments brain tumors using a U-Net-based model, then classifies them into benign, primary malignant (gliomas), or metastatic tumors. Using multi-institutional datasets from TCIA, we aim to create a robust and generalizable model to assist radiologists with diagnosis and triage.

PROBLEM STATEMENT

Manual interpretation of brain MRI is resource-intensive, and tumor identification and grading are susceptible to inter-observer variability. While previous AI models have focused on segmentation or glioma grading (HGG vs. LGG), there have been few efforts to combine segmentation with multi-class classification (benign vs. primary malignant vs. metastatic). A unified model could greatly improve diagnostic support systems, especially in resource-limited settings.

DATASETS(s) TO BE USED

We utilize multi-institutional, publicly available datasets downloaded from The Cancer Imaging Archive (TCIA), including:

- BraTS-Africa and MU-Glioma: For segmentation and classification of primary brain tumors (LGG/HGG/GBM)
- BCBM, Pretreat-Mets, Yale Brain Mets: For metastatic tumors
- ReMIND and others: For benign tumors (e.g., meningiomas, pituitary tumors)

These datasets include annotated masks, MR sequences (T1, T2, FLAIR, T1ce), and clinical information.

APPROACH

1. Segmentation:

- Train a 3D U-Net in PyTorch on glioma cases with annotated tumor masks.
- Fine-tune on metastatic and benign cases (if segmentations available or via weak labels).

2. Feature Extraction:

- Extract deep features from the segmented region using a pretrained encoder.

3. Classification:

Build a classifier (e.g., CNN or shallow MLP) to categorize cases into:

- Benign
- Primary Malignant (Glioma)
- Metastatic Tumor

4. Evaluation:

- Segmentation: Dice score, Hausdorff distance
- Classification: Accuracy, AUC, confusion matrix

5. Visualization:

- Overlay segmentation results and saliency maps for interpretability.

Expected Outcomes

- A trained 3D U-Net model for brain tumor segmentation across diverse tumor types.
- A multi-class tumor classification model with performance metrics.