AI- MedX

ABSTRACT

TEAM NAME : localhost

Brain metastases, secondary tumors that originate from cancers in other parts of the body and spread to the brain, present significant diagnostic challenges. Early and accurate detection is critical for effective treatment planning and improved patient outcomes. Traditional methods of brain metastases diagnosis rely heavily on manual interpretation of magnetic resonance imaging (MRI) scans by radiologists. This process is time-consuming, subject to human error, and prone to inter-observer variability, which can delay treatment decisions. To address these challenges, this study explores the application of **artificial intelligence (AI) and deep learning models** to automate brain metastases detection through **3D semantic segmentation** of MRI scans.

This project leverages the **BraTS 2024 Metastasis Dataset**, which includes multi-modal MRI images such as **T1, T1 contrast-enhanced (T1c), T2, and FLAIR** sequences, along with expert-annotated segmentation masks that delineate tumor regions. The proposed AI solution employs three advanced deep learning architectures: **U-Net, Attention U-Net, and ResU-Net**, each optimized for accurate tumor segmentation. **U-Net** is a widely used medical image segmentation model, while **Attention U-Net** enhances feature extraction by incorporating attention mechanisms to focus on tumor-relevant regions. **ResU-Net**, on the other hand, introduces residual connections that improve gradient flow and enable deeper network training, reducing the risk of vanishing gradients.

To optimize performance, the project implements a robust **data preprocessing pipeline**, including **image normalization, cropping, resizing, and one-hot encoding** of segmentation masks. Additionally, **data augmentation techniques** such as random slice selection are employed to improve model generalization and prevent overfitting. The study also addresses class imbalance—where tumor regions are significantly smaller than the overall brain volume—by using **Weighted Dice Loss and Categorical Focal Loss** during training.

The effectiveness of each model is evaluated using **multiple performance metrics**, including **Dice Similarity Coefficient (DSC), Intersection over Union (IoU), accuracy, precision, recall, and F1-score**. Experimental results indicate that **Attention U-Net achieves the highest validation accuracy (97.54%)**, demonstrating its superior ability to generalize across different patient MRI scans. **ResU-Net follows closely with 97% validation accuracy**, benefiting from residual connections that enhance feature learning. **Standard U-Net, while achieving 95.41% training accuracy, slightly underperforms in validation (94.08%), suggesting minor overfitting.**

This research highlights the potential of deep learning in transforming brain metastases diagnosis by improving **accuracy, speed, and consistency** in clinical decision-making. By leveraging AI, this project aims to **reduce diagnostic delays, enhance patient outcomes, and advance precision medicine in neuro-oncology.**