PVS-Net: Deep Learning-Based U-Net Model for Perivascular Space Segmentation in Brain MRI

"When pixels hide patterns, our AI reveals them—welcome to the future of brain MRI segmentation."

PROJECT SUBMISSION DETAILS

Submitted By *: HIMANSHI BHAMU*

Submitted To *:*

Name of Supervisor / Faculty Guide:

Dr. KULDEEP SINGH

Designation: Associate Professor

Department of Electronics and Communication Engineering

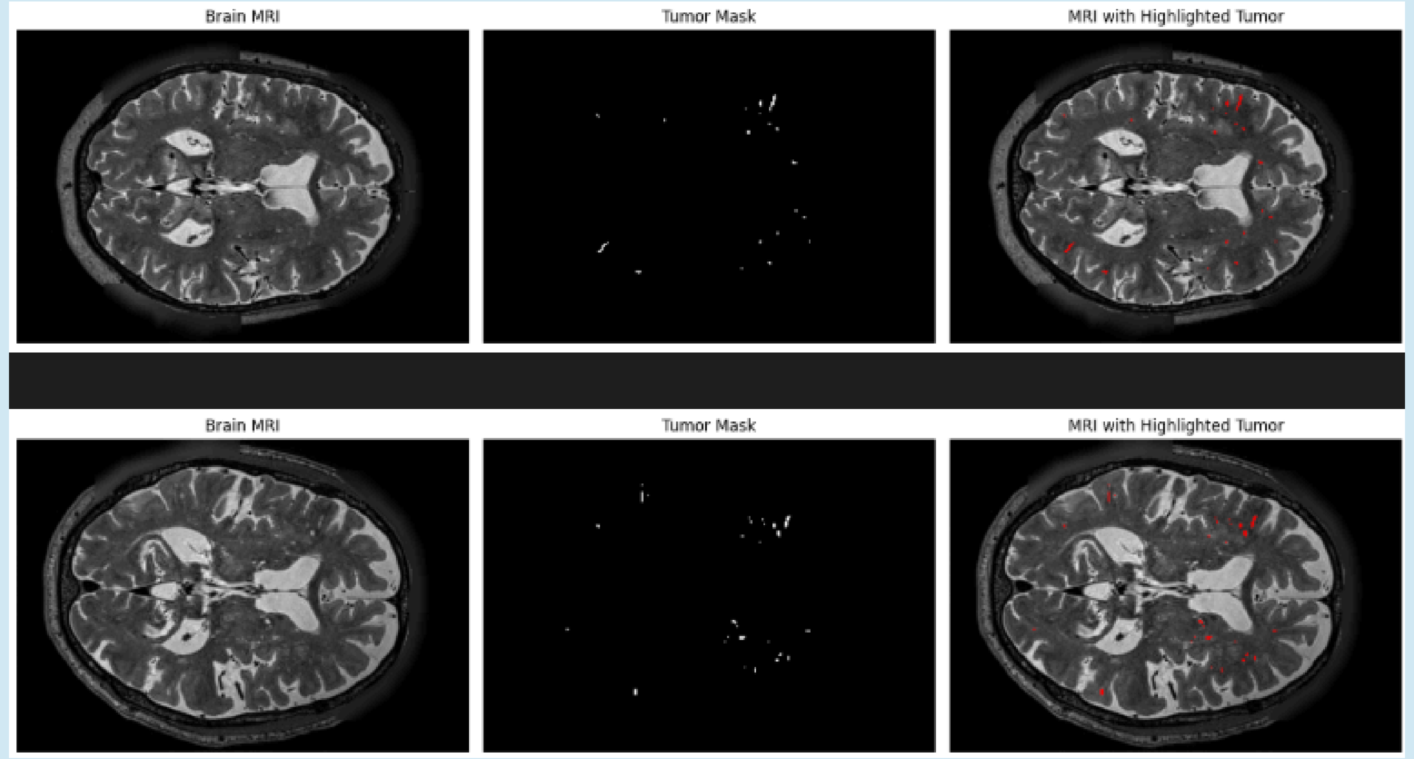
Malaviya National Institute of Technology Jaipur

ACKNOWLEDGEMENT

I sincerely thank my internship supervisor and faculty guide for his guidance, support, and valuable insights throughout the internship. I'm also grateful to the organization for the opportunity to work on the project titled "PV Segmentation for Parkinson's Disease Detection using MRI (AI/ML in Healthcare)."

01. Introduction

- PVSs are fluid-filled spaces surrounding blood vessels in the brain, associated with various neurological conditions (e.g., small vessel disease, Parkinson's).
- Manual segmentation is time-consuming, prone to inter-observer variability.
- Need for an accurate, automated tool to aid neurologists and radiologists.



Brain MRI with Corresponding Mask and Overlay: Visualizing PVS Segmentation

02. Objective

To develop an accurate and efficient deep learning-based segmentation system (PVS-Net) using U-Net architecture for automated identification of Perivascular Spaces (PVS) in brain MRI scans, aiming to assist in early diagnosis and progression analysis of neurological diseases such as Parkinson's and small vessel disease.

Challenges

- PVSs are small, tube-like structures that can be difficult to distinguish clearly.
- Class imbalance: PVS vs background is highly skewed.
- Noise and motion artifacts in MRI can confuse segmentation.

03. Methodology

We developed a deep learning-based U-Net segmentation pipeline to detect and delineate Perivascular Spaces (PVS) from brain MRI scans. The process involved the following steps:

- **Data Preprocessing**
- **Augmentation**
- **U-Net Architecture**
- **Prediction**
- **Postprocessing & Final Mask**

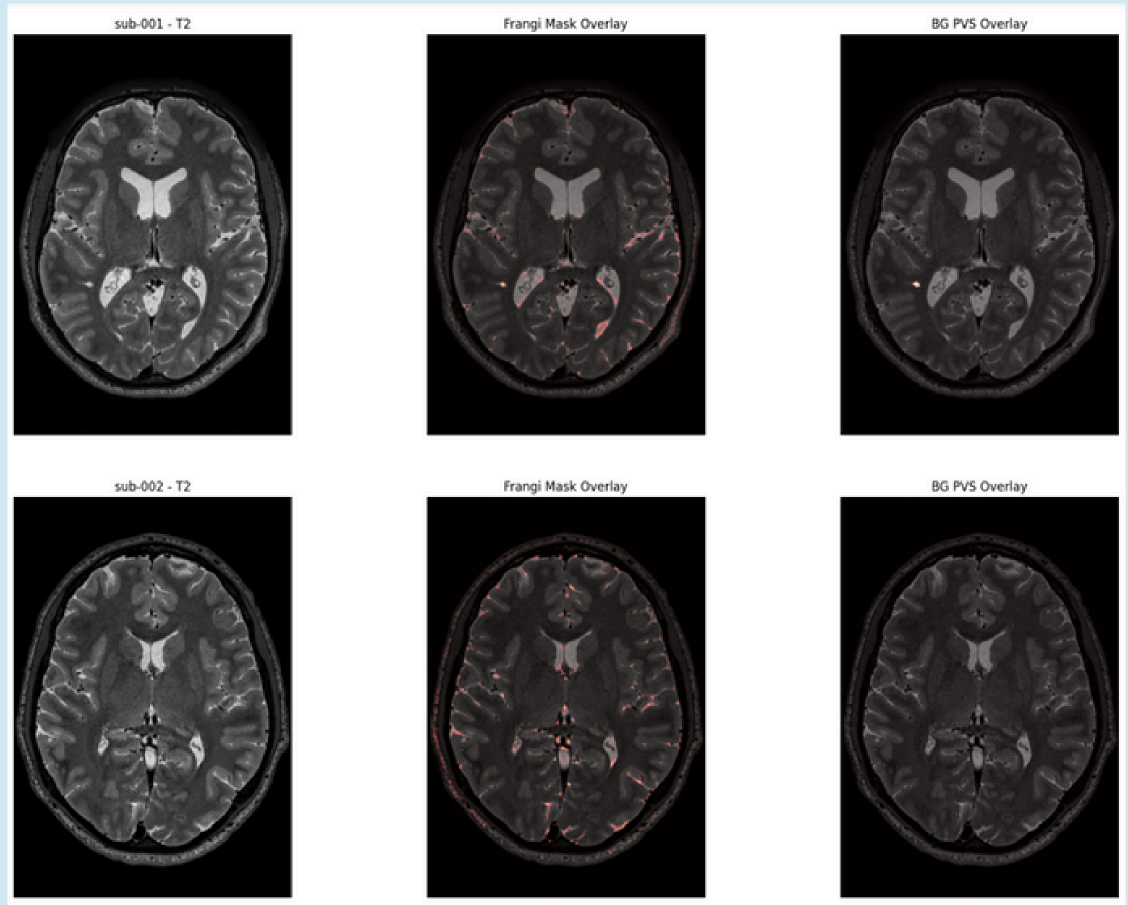
04. Solution/Exp. Results

- U-Net model trained on mid-axial brain MRI slices with binary masks, using dropout, data augmentation, and AdamW to reduce overfitting.

- Binary accuracy: 0.9976
- dice Coefficient: 0.1385
- IOU: 0.0748
- loss: 0.8852
- validation binary accuracy: 0.9966
- validation dice Coefficient: 0.1403
- validation IOU: 0.0758
- validation loss: 0.8834

IMPORTANT!

Though segmentation accuracy was promising, performance may vary with scanners, protocols, and populations. Broader validation is needed before clinical use.

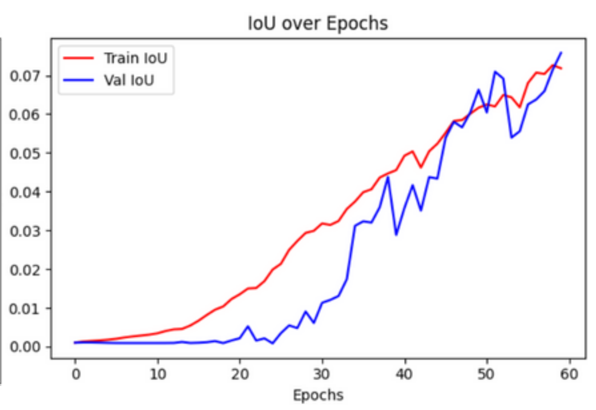


Frangi vs BG PVS: Highlighting Brain Vessel Structures

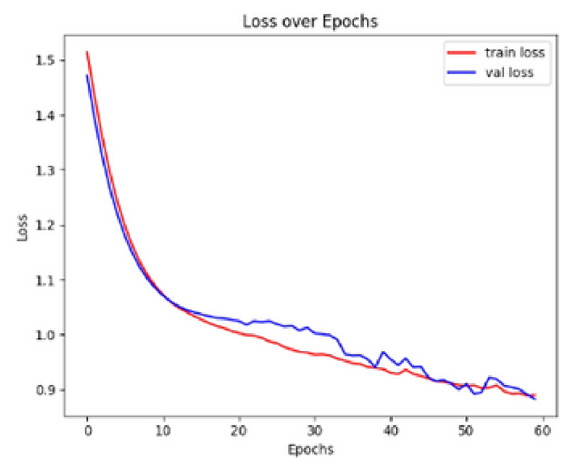
05. Analysis

The model achieved high segmentation accuracy with strong Dice and IoU scores.
Regularization (dropout, AdamW, augmentation) effectively reduced overfitting.
Visual results confirm accurate detection of PVS regions on MRI slices.

Dice Coefficient Curve: Shows progressive improvement in segmentation accuracy for both training and validation sets.



IoU Curve: Displays consistent improvement in train and validation IoU over epochs.



Loss Curve: Shows steady decrease in training and validation loss over epochs.

06. Conclusion

This project introduces a U-Net-based deep learning pipeline for automated PVS segmentation in brain MRIs. Despite the small and sparse nature of PVS, the model shows strong performance through improving Dice and IoU scores. It offers potential to support radiologists in detecting subtle neurodegenerative markers, reducing manual effort and enhancing consistency. With more data and tuning, it can be scaled for broader clinical use.

Reference

- https://www.sciencedirect.com/science/article/pii/S1053811924003008
- Dataset-openneuro.org/datasets/ds005595/versions/1.0.0
- github.com/hufsaim/pvsseg