Comparative Study of Deep Learning Models for Post-Stroke Lesion Detection

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Source Code: https://github.com/wannasleepforlong/Analysis-of-Anatomical-Tracings-of-Lesions-After-Stroke

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Introduction

Stroke, a neurological event, leaves lasting impacts on millions globally. Accurate analysis of stroke lesions in brain scans is paramount for effective treatment planning and improved patient outcomes.

Traditionally, this analysis involves manual segmentation of lesions by medical professionals, a method hindered by time constraints and reliance on individual expertise. Deep learning has emerged as a promising tool for automated stroke lesion segmentation, offering advantages over traditional manual methods.

This project delves into the potential of deep learning to automate stroke lesion segmentation using deep learning architectures such as X-Net, V-Net, Seg-Net and U-Net, which have achieved significant success in this domain and are specifically designed for segmentation.

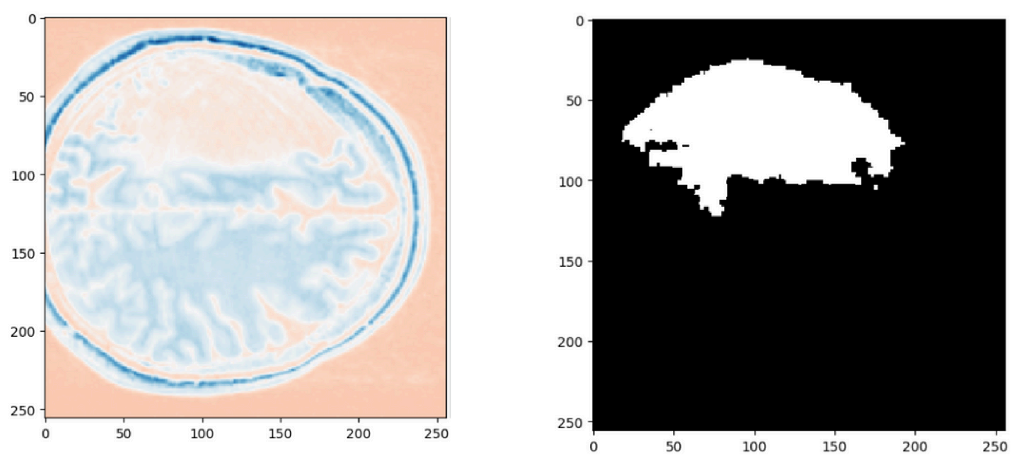

Figure 1: An example of high-resolution T1-weighted structural MRI scan of a patient post-stroke and the manually segmented diverse lesion.

Objectives

- The primary aim of this study is to comprehensively evaluate and compare the efficacy of four distinct convolutional neural network architectures, namely X-Net, V-Net, Seg-Net, and U-Net, in the context of segmenting stroke lesions from medical imaging data.
- By meticulously scrutinizing the segmentation capabilities of X-Net, V-Net, Seg-Net, and U-Net in the specific domain of stroke lesion identification from medical imaging data, our objective is to provide insights into their respective performances and potential contributions to enhancing stroke lesion segmentation accuracy.

Results & Discussion

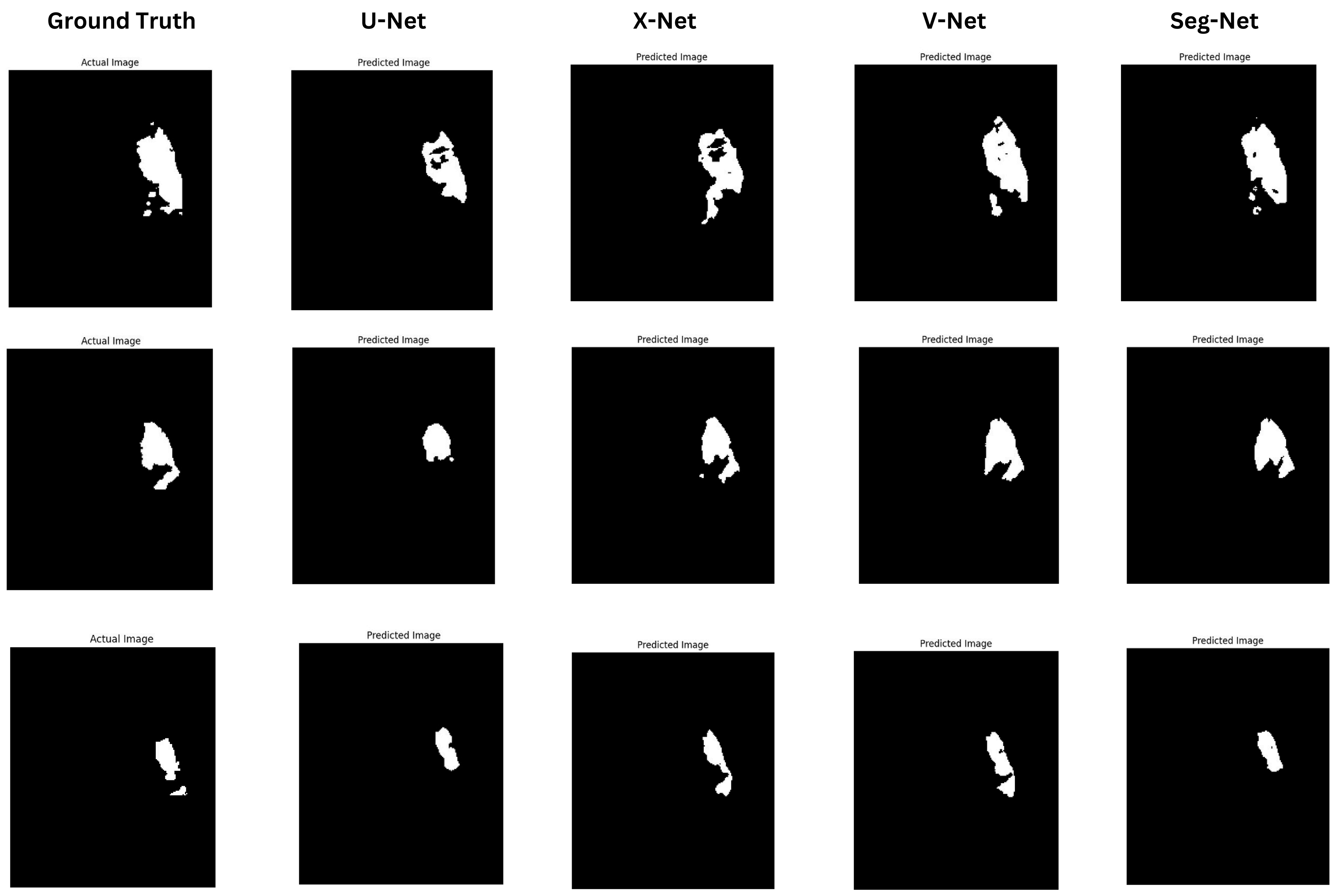

Figure 3 : Results of the segmented brain scan lesion predictions by different models with respect to the actual ground truth images.

The evaluation of deep learning models for lesion segmentation revealed distinct performance characteristics among the tested architectures. X-Net demonstrated exceptional training accuracy and Dice coefficient, indicative of its adeptness in identifying lesion regions. However, its elevated training and validation losses hint at potential overfitting issues. Conversely, U-Net displayed consistent performance but struggled with higher validation loss, suggesting room for improvement in generalization. V-Net exhibited promising results, boasting strong training metrics and impressive generalization capabilities, positioning it as a viable contender for stroke lesion segmentation tasks. Notably, SegNet emerged as a top performer, achieving high accuracy and Dice coefficient while maintaining low training and validation losses, underscoring its efficacy in accurately delineating stroke lesions

Methodology

The project began with a comprehensive popularity analysis of the deep learning models under consideration for stroke lesion segmentation. U-Net and SegNet emerged as the most popular models, with a combined total of over 18,000 citations. V-Net followed with nearly 9,764 citations, while X-Net had relatively fewer citations, around 145. The results produced by these models were further compared, with a focus on evaluating the segmentation images based on their accuracy.

We utilized a dataset comprising MRI scans of patients with confirmed stroke lesions. This project utilizes data from the publicly available Anatomical Tracings of Lesions After Stroke (ATLAS) [1]. The dataset comprises 955 T1-weighted MRIs, divided into a training dataset of 655 scans with manually segmented lesion masks and a test dataset of 300 scans without released lesion masks for unbiased performance evaluation. The data used in this analysis consists of MRI scans from 66 patients.

The methodology involved a comprehensive data preprocessing pipeline to prepare neuroimaging data for training deep learning models. The preprocessed data was stored in an efficient HDF5 format for model training and evaluation. The training process consisted of two phases: pretraining on filtered 2D slices and training on full brain MRIs from a patient cohort. Pretraining utilized 2D slices with actual brain lesions, retaining only those with ≥2.5% lesion coverage (5000 slices) to discern intricate lesion features across brain regions.

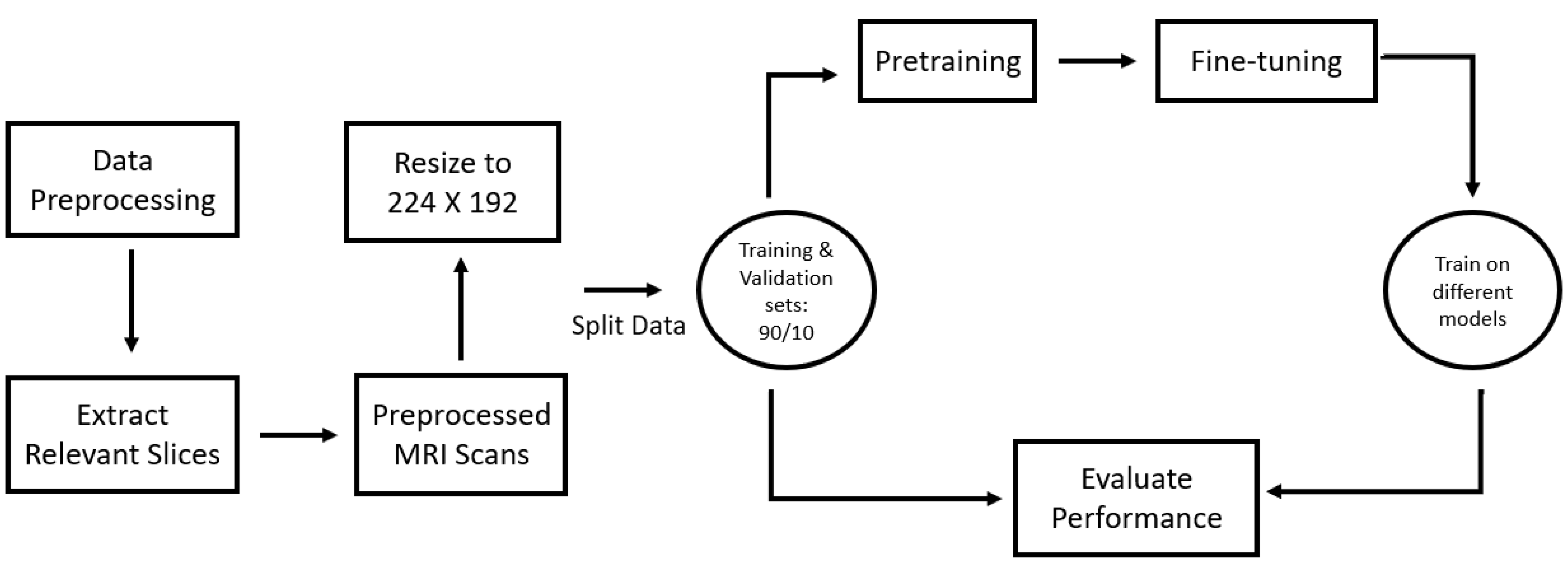

Figure 2: Post stroke brain lesion segmentation comparative study using deep learning models X-Net, V-Net, U-Net and Seg-Net.

Subsequently, the model was trained on complete brain MRI scans from 66 patients, enabling it to generalize and segment lesions within the entire brain anatomy. Four deep learning models were implemented and evaluated: XNet, U-Net, VNet, and SegNet. Model performance was evaluated using standard metrics, including Dice Similarity Coefficient, Intersection over Union, Accuracy, quantifying the overlap between predicted and ground truth segmentations. The models were trained using a combined loss function consisting of binary cross-entropy and Dice loss. The Adam optimizer was used for weight updates, with a learning rate of 1e-3. The segmentation images produced by the models were compared based on their accuracy, highlighting the strengths and limitations of each approach.

Conclusion

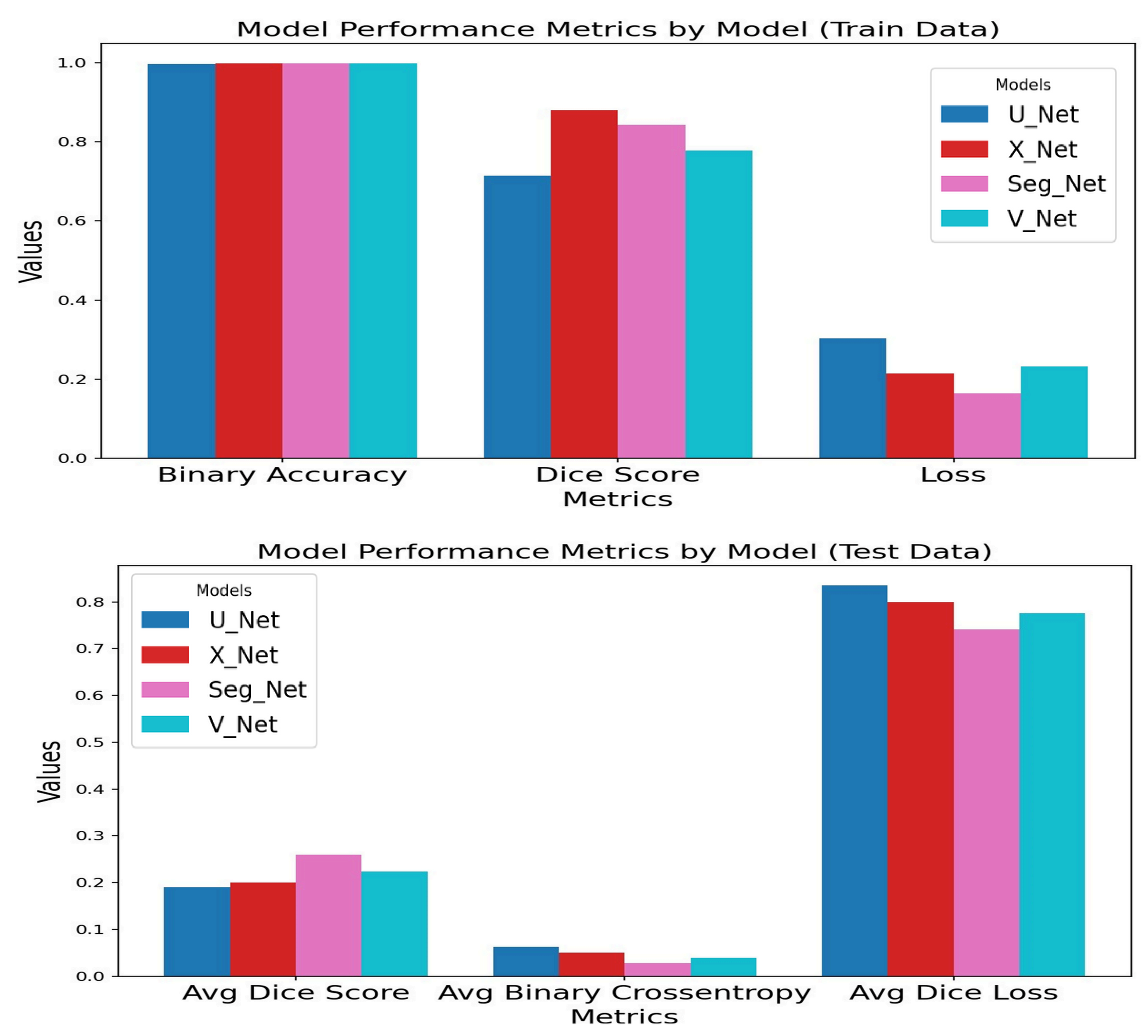

Figure 4 : Bar graphs comparing the performance of U-Net, Seg-Net, V-Net, and X-Net models on lesion segmentation in brain MRI scans for the training data & test data.

Future Work

- This preliminary analysis could serve as a valuable aid for technicians before consulting with experts or specialists, enabling faster triage and potentially accelerating the overall diagnostic workflow.
- A user-friendly software application could be developed that assesses the patient before doctor intervention.

References

1. Liew, SL., Anglin, J., Banks, N. et al. A large, open source dataset of stroke anatomical brain images and manual lesion segmentations. Sci Data 5, 180011 (2018).
2. Wang W, Kiik M, Peek N, Curcin V, Marshall IJ, Rudd AG, Wang Y, Douiri A, Wolfe CD, Bray B. A systematic review of machine learning models for predicting outcomes of stroke with structured data.