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AUTOMATIC BIOMEDICAL BRAIN TUMOR SEGMENTATION FOR DISEASE DIAGNOSIS USING ARTIFICIAL INTELLIGENCE

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ABSTRACT

Brain Tumor problems can lead to various health issues like Nausea, Memory Loss and vision problems and have a significant impact on daily life which requires early diagnosis and treatment to get saved from further damage and complications. Recent enhancement in Image processing and Artificial Intelligence have brought notable transformations in healthcare technology, leading to significant improvements in diagnosis accuracy, cost-effectiveness, and time efficiency. Magnetic Resonance Imaging (MRI) is employed by the radiologist for its remarkable ability to detect even the most critical and tiny brain abnormalities. This study considers a comprehensive segmentation frameworks – U-Net, U-Net++ and Modified U-Net, leveraging state of-the-art deep learning architectures to segment brain cancers within MRI. To confirm detailed segmentation of the tumor regions, the preprocessing phase includes advanced mask alignment techniques. This pre-processed dataset has been used to evaluate the performance of the deep learning models for brain tumor segmentation. Modified U-Net backbone architecture-based customized deep-learning model is built to segment brain tumors which enhances feature extraction and multi-scale feature fusion. From the numerical results of modified U-Net, it was noticed that a validation accuracy of 0.99756, validation IoU of 0.8014 and dice co efficient of 0.8880. In comparison, modified U Net exhibits strong performance with box detection accuracy of 0.99768, validation IoU of 0.8131 and dice co efficient of 0.8952. To underscore the novelty of the approach, the performance of the proposed framework is systematically compared with established methods such as U-Net, U-Net. These findings showcase the robustness, generalizability and effectiveness of the proposed modified framework for proper image segmentation contributing towards advanced medical technologies and diagnosis precision..

Keywords:
Brain tumor, deep learning, image processing, MRI, U-Net, IoU, Dice coefficient.

INTRODUCTION

It makes the diagnosis of brain tumors one of the high-risk tasks in medico areas where timely detection can radically change the fate of the patient. Traditional diagnosis techniques of brain tumors, for instance, MRI, CT scan, biopsy, usually are invasive, time-consuming, and prone to some sort of human error in results. There is, therefore, a premise for methodologies to be more advanced to improve both efficiency and accuracy in diagnosis. The potential of applying artificial intelligence, and machine learning in particular, has been utilized over the past few years, and new techniques have already shown significant promise towards the advancement in medical image-based brain tumor detection and segmentation. Deep neural networks for image segmentation are probably one of the most prominent developments in this regard. In medical image analysis for brain tumor, segmentation is a very critical step because it helps to bring out the exact boundaries of the tumor from the healthy tissue. Confronted with the complexity and variability of those images, traditional image segmentation methods normally fail to deliver; medical images are very prone to the effects of noise, irregularities in illumination, and anatomical differences between patients. Importantly, recent deep-learning models, such as the U-Net architecture, have shown promising performance in relevant-feature automatic learning and corresponding accurate segmentation masks production for the above task. U-Net, invented for biomedical image segmentation, has gained wide popularity, naturally succeeded by encoder decoder architectures that capture high-and low-level features. However, its successes can still be improved with respect to handling intricate details and variations in brain MRI images. The unfolded recommendation of the research paper is a modified U-Net model with brain tumor segmentation advanced by techniques like bi-directional feature pyramid networks and multi-scale feature fusion. These improved techniques will make it able to catch the fine details and complex interactions inside the images, therefore producing more accurate segmentation results. Equipped with these novelties, this modified U-Net model will further provide a very resilient and efficient framework for brain tumor segmentation. In particular the current work mainly contributes to the development of a comprehensive framework for segmentation, intensive experimentation conducted on a dataset of MRI images of the brain, and in depth assessment of model performance with accuracy and dice coefficient among others. Such an approach has huge potential for the improvement of diagnosis and treatment of brain tumors and, as a result, for better care of patients with this dangerous disease. This advancement in segmentation technology can be of much help to clinicians in making wiser decisions by reducing the likelihood of misdiagnosis and hence enhancing the general effectiveness of strategies for treatment.

OBJECTIVES

The goal of this project is to develop and assess deep learning-based frameworks for the precise segmentation of brain tumors in MRI images. The primary goal is to enhance the accuracy of tumor detection through the use of advanced deep learning architectures, including U-Net, U-Net++, and a modified U-Net model. The modified U-Net aims to improve feature extraction and multi-scale feature fusion, allowing for better detection of complex tumor structures. The study also focuses on evaluating the performance of these models using key metrics such as validation accuracy, Intersection over Union (IoU), and Dice coefficient to ensure reliable and accurate segmentation. Additionally, the research incorporates advanced preprocessing techniques, such as mask alignment, to further improve segmentation results. By comparing the performance of the proposed modified U-Net model with traditional models like U-Net and U-Net++, the study demonstrates the enhanced effectiveness, robustness, and generalizability of the modified approach. Ultimately, the goal is to contribute to the advancement of medical technologies and improve the precision of brain tumor diagnosis, aiding in earlier detection and better treatment outcomes..

METHODOLOGY

It is cautiously ensured that high-quality inputs are put into the model through data preprocessing and selection. Later, the model is trained and evaluated using the following steps with the standard parameters:

A. DATA COLLECTION : The The authors experiment on these datasets with the Brain Tumor dataset, received from studies of Mateusz Buda et al. (2019) and Maciej A. Mazurowski et al. (2017), with segmentation masks relating the ground truth and 1965 brain MRI images of abnormalities in manual FLAIRs. The images were downloaded from The Cancer Imaging Archive and were obtained for the 110 subjects acquired for the TCGA lower-grade glioma patient set, where each subject has at least a FLAIR sequence and genomic cluster data in the minimum. All tumor genomic clusters and patient data were maintained in a data.csv file for complete analysis and evaluation.

B. DATA PREPROCESSING : The initial data are in the .tif format and include MR images of the brain and corresponding manual FLAIR abnormality segmentation masks. These datasets were pre-processed, which covered rotation, resizing, and augmentation, among others, to finally make the model perform well and be generalized. These preprocessing steps ensure the dataset is well-prepped for training and evaluating the modified U-Net.

C. DATA SELECTION : It involves 1965 brain MRI images and their associated masks indicating tumor locations. These are based on the research of Mateusz Buda, Ashirbani Saha, and Maciej A. Mazurowski in Computers in Biology and Medicine, 2019, and Journal of Neuro-Oncology, 2017. These images were sourced from The Cancer Imaging Archive (TCIA); they areimages of subjects in the collection for lower-grade gliomas available in The Cancer Genome Atlas with at least FLAIR sequence and genomic cluster data. Tumor genomic clusters and patients' information were provided in a data.csv file. The dataset, initially in .tif format, has undergone resize androtate preprocessing steps. After preprocessing, the dataset was divided into three portions.

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D. MODEL TRAINING : Two variants of the U-Net model, including the standard U Net and a modified U-Net with additional add and multiply layers in the decoder part, are employed in this research work for brain tumor segmentation and classification. The selection of these variants is aimed at facilitating a comprehensive assessment of their capabilities and gauging their effectiveness in addressing the challenge of tumor detection and classification.

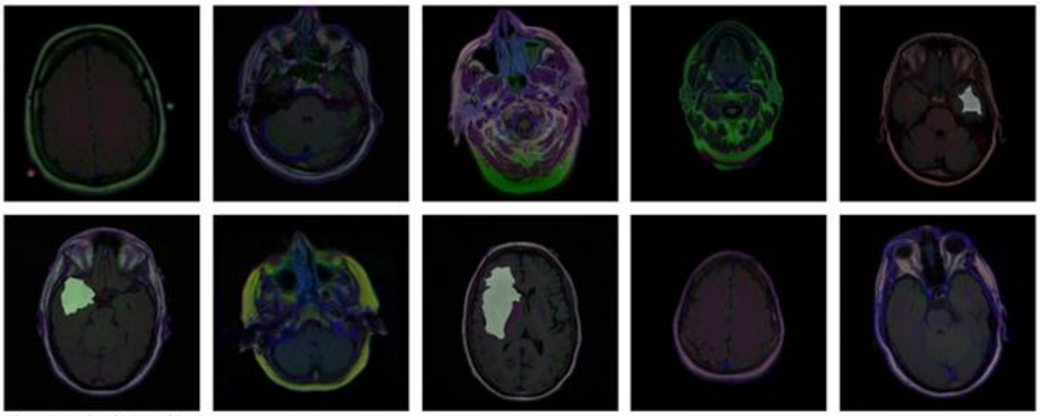
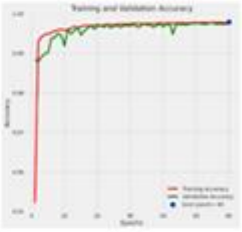


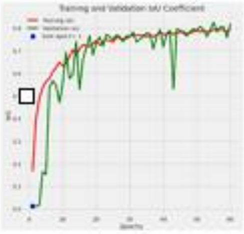
Figure 1 Sample of MRI of Brain

RESULTS AND DISCUSSION

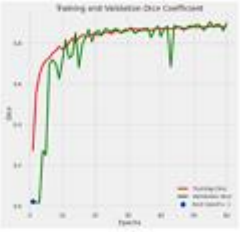
In this work, the proposed modified U-Net model for brain tumor segmentation is evaluated against the original U-Net. The dataset consists of 1965 brain MRI images and their corresponding manual FLAIR abnormality segmentation masks. Images were meticulously pre-processed and split into training, validation, and test sets. There are 1375 images in the training set, 295 in the validation set, and 295 in the test set. It uses the metrics of Accuracy, Dice coefficient, and Intersection over Union to gauge the performance of both models. For the original U-Net model, a validation accuracy of 0.99756, a validation IoU of 0.8014, and a Dice Coefficient of 0.8880 were attained. In contrast, the modified U-Net model improved with added addition and multiplication layers in its decoder part. The validation accuracy achieved by the modified model was 0.99768. In addition, the validation IoU achieved the value of 0.8131, while a Dice coefficient of 0.8952 was obtained. It clearly depicts that the extra layers added to the decoder part of the U-Net architecture strengthen the model's capability of capturing and integrating multi-scale contextual information. This improvement is well reflected in the increased values of accuracy, Dice coefficient, and IoU, which indicates better segmentation performance. The comparative analysis of the original and modified U-Net models itself proves the effectiveness of the proposed modifications. In this regard, small yet constant improvements in all metrics of evaluation do reflect the potential of this modified U-Net model for brain tumor segmentation with increased accuracy and reliability. This kind of increase in performance is very important in clinical applications when the exact delineation of the tumor is an unconditional requirement for treatment planning and monitoring. Moreover, the comparative analysis between the original and modified U-Net models only goes to prove the effectiveness of the proposed modifications. Subtle improvements in all the carrying evaluation metrics provided proof of concept regarding the potential of the modified U-Net model for brain tumor segmentation with high reliability and accuracy. Precisely, such improved performance is vital in the clinical setting where accurate tumoral demarcation plays a very cogent role in treatment planning and monitoring.



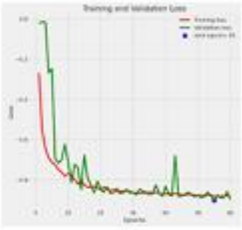
Accuracy Graph



IoU Coefficient Graph



Dice Coefficient Graph



Loss Graph

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CONCLUSION

The modified U-Net model contributed a strong and effective method for brain tumor segmentation. In particular, it outperformed the traditional U-Net in almost all key performance metrics. This paper proved that adding extra layers within the decoder part of the U-Net architecture could remarkably improve the segmentation accuracy of brain MRI images. Future studies may further investigate enhancements and validations on larger and more diverse datasets for confirming these findings and probably explore the integration of this model clinically.

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