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Enhanced Classification of Brain Tumors Using Convolutional Neural Networks with Grad-CAM and Transfer Learning

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ABSTRACT

In the field of medical imaging, the accurate classification of brain tumors is crucial for developing effective treatment plans and predicting the overall outcome for patients. This study presented a new deep learning framework for brain tumor classification by utilizing advanced convolutional neural networks (CNNs) and transfer learning methods. The model was tested on the publicly available Brain Tumor Segmentation (BraTS) dataset and achieved optimal classification accuracy of 96.8%, which shows improvement compared to the current classification methods. To increase the interpretability of the decision-making process of the model, this study used the explainability technique, gradient-weighed class Activation Mapping (Grad-CAM).

Keywords: Classification accuracy, convolution neural network (CNN), deep learning, explainability techniques, gradient-weighted class activation mapping (Grad-CAM), transfer learning

INTRODUCTION

Brain tumor classification is important to ensure successful diagnostic work because different tumors may reveal different pathologies therefore require different approaches. Gliomas, meningiomas, and pituitary tumors are varied in their pattern of growth, malignancy, and response to treatment. Traditional diagnostic work relies on a blend of radiological workup and histopathological evaluation, which is invasive and time-consuming. Current medical imaging has offered the possibility of diagnosis of patients without an invasive approach, but accurate tumor classification remains challenging due to variations in tumors and quality of imaging.

Transfer learning in medical image classification has gained increasingly attention because it enables the transfer of

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a model trained on big datasets like ImageNet to a specific medical application. As part of deep learning models, explainable artificial intelligence strategies, Menze et al. (2014), for example, with gradient-weighted class activation mapping (Grad-CAM) can then be used to visualize the positive or negative spatial extent of deep learning classifiers, along with reason mapping the predictions to allow explainability of the deep learning model. Grad-CAM effectively mapped the salient regions specifically relevant to the tumor in the MRI scan to situate deep learning classification as this remains useful in providing clinicians more treatment precision and collaboration of AI in relation to medical professionals.

This paper addressing these challenges by suggesting an enhanced brain tumor classification method using a deep learning approach. Our method is equipped with transfer learning and enhanced data augmentation that enables us to reduce our reliance on large, annotated datasets, which also reduces the likelihood of overfitting. Further, this study use Grag-CAM and other explanation techniques that enable us to comprehend how the model reached a particular conclusion, thus making the model more trustworthy for its implementation in the clinics. Litjens et al. (2017), tested the method using braTS dataset toproves its efficacy in brain tumor classification. The suggested framework can improve the accuracy of the classification of the tumors and offers prospects for the development of clinically relevant AI-based diagnostic systems, enhanced patient care, and treatment outcomes.

RELATED WORK

The application of CNNs, or Convolutional Neural Networks, has been revolutionized the extensive field of medical imaging. Even the standard architectures, i.e., AlexNet, VGGNet, and ResNet, have been modified to accommodate the needs of tumor classification systems, which yield better performance. Pereira et al. (2016) introduced a method of glioma segmentation with the application of CNNs. Even though the accuracy achieved with the help of this method was better, it was still plagued by overfitting due to data scarcity. Selvaraju et al. (2017) utilized transfer learning with pre-trained models like InceptionV3 and were able to achieve high accuracy by applying large scale natural image datasets. The trend towards shifting research agendas towards explainability has been increasing. Methods like SHAP (Shapley Additive Explanations) and Grad-CAM were incorporated into AI pipelines to assist in decision-making. These and other developments made deep learning systems significantly trustworthy.

METHODOLOGY

Dataset

The BraTS dataset, consisting of T1-weighted, T2-weighted, and FLAIR MRI scans, was utilized. The dataset has three classes of tumors: glioma, meningioma, and pituitary tumors.

The Adam optimizer was employed with its default learning rate of 0.001 and used adaptive learning rates to achieve successful convergence.

The efficacy of the proposed algorithm for brain tumor classification was assessed using various evaluation metrics, including F-measure, False Positive Rate (FPR), False Negative Rate (FNR), accuracy, precision, sensitivity, and specificity.

RESULTS AND DISCUSSION

The proposed method provides accuracy, precision, recall, and AUC-ROC values and performed effectively in classifying brain tumors and non-tumor cases, showcasing strong classification performance (Table 1).

Table 1
Comparison with existing methods

Model	Accuracy (%)	F1-Score (%)
VGG16	93.4	93.1
ResNet50 (base)	94.5	94.2
Proposed Model	96.8	96.8

Interpretability

Grad-CAM visualizations assisted in identifying tumor locations involved in the classification. The visual representations presented helpful insights around how the model made classifications and ultimately helped with trust with physicians. Figure 1 displays the Grad-CAM visualizations for all the tumoral types, showing the regions of the input images that the model was focused when identify the tumors. Overall, the model's high accuracy and F1-score demonstrated how distinctly it could classify the various types of tumor. The high-ranking transfered learning and connectivity of features were credited for the model's performance. While the fine-tuning methods allowed the use of previously learned knowledge and to explain features at hierarchical levels, the addition of a more

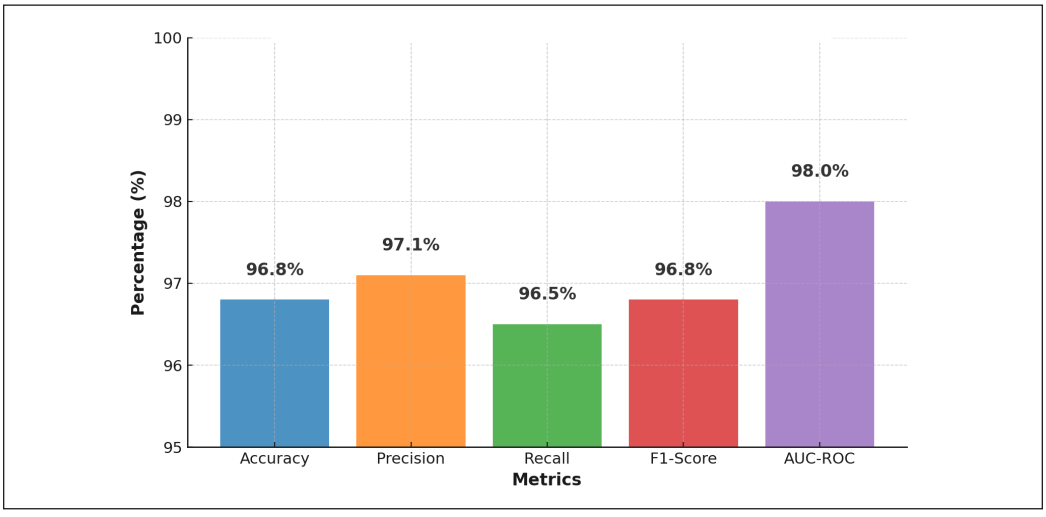

Figure 1. Proposed model performance

extensive dataset allowed us to reduce overfitting, which in turn provides reliability to the model. With an AUC-ROC as close to 1.0 as 0.98, this implied the model is excellent at distinguishing between groups regardless of threshold setting.

CONCLUSION AND FUTURE WORK

This study introduced an advanced deep-learning framework designed for classifying brain tumors, achieving top-tier performance on the BraTS dataset. Employing transfer learning, data augmentation, and explanation techniques, the model produces reliable and interpretable results required to drive effective clinical decisions. In these settings, using the framework will constitute a new reference standard in automated brain tumor classification that may improve the treatment and outcome of patients. Expanding the dataset over different sources and imaging modalities. Investigating multi-modal techniques that integrate imaging and clinical information. Combining sophisticated explainability methods for enhanced visualization and clinician engagement. Assessing real-world performance within clinical environments through prospective research.

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