Evaluation of Hybrid CNN Models for Binary Brain MRI Classification

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Abstract

This study presents a novel hybrid approach for brain tumor detection using magnetic resonance imaging (MRI) scans from The Cancer Imaging Archive (TCIA) . The proposed model combines feature extraction techniques like Histogram of Oriented Gradients (HOG) and Local Binary patterns (LBP) with a deep learning methodology (Convolutional Neural Network (CNN) based on ResNet50). This multimodal architecture processes traditional texture and edge features with deep learning representations, leveraging both handcrafted and learned features to enhance classification performance. Employing a 5-fold cross-validation strategy on 5,264 images, the model achieved exceptional performance with the average results across all folds being: validation accuracy (0.9967), precision (0.9999), recall (0.9945), and an F1 score of (0.9969), showcasing superiority over other models. Notably, our approach demonstrated consistent performance across training and validation sets, mitigating common overfitting issues observed in other models. Comparative analysis against established architectures such as VGG16, ResNet50, and a regular CNN showed that our model outperforms these alternatives in classification accuracy and robustness. This research contributes to medical image analysis by demonstrating the potential of hybrid models to revolutionize the field of brain tumor diagnosis Brain tumor detection , Feature extraction, CNN, Data augmentation

1 Introduction

Brain tumors represent a significant challenge in modern healthcare, with an estimated global incidence of 10.82 per 100,000 person-years. The accurate and timely diagnosis of these neoplasms is crucial for effective treatment planning and improved patient outcomes. Magnetic Resonance Imaging (MRI) has emerged as the gold standard for brain tumor detection and characterization, offering superior soft tissue contrast and multiplanar imaging capabilities. However, the interpretation of MRI scans remains a complex and time-consuming task, often subject to inter-observer variability and human error.

In recent years, the field of artificial intelligence (AI), particularly deep learning, has shown remarkable potential in revolutionizing medical image analysis. Convolutional Neural Networks (CNNs) have demonstrated exceptional performance in various image classification tasks, including the detection and segmentation of brain tumors. Notable architectures such as VGG16 and ResNet50 have been successfully adapted for medical imaging applications, achieving high accuracy in tumor detection.

Despite these advancements, several challenges persist in AI-based brain tumor detection. These include the risk of overfitting due to limited dataset sizes, the need for interpretable models to gain clinician trust, and the difficulty in balancing sensitivity and specificity. Additionally, while deep learning models excel at learning complex patterns, they may overlook subtle textural features that are crucial for accurate tumor detection.

Concurrently, traditional computer vision techniques such as HOG and LBP have a proven track record in capturing fine-grained textural and edge information in images. These methods, while less complex than deep learning approaches, offer the advantage of interpretability and efficiency in feature extraction.

The potential synergy between traditional feature extraction methods and deep learning techniques remains largely unexplored in the context of brain tumor detection. This gap in current research presents an opportunity to develop a hybrid approach that leverages the strengths of both paradigms, potentially leading to more robust and accurate tumor detection systems.