Multi-Class Brain Tumor Classification and Grade Estimation using Dual-Head Neural Network

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Abstract

Accurate and timely diagnosis of brain tumors remains a critical challenge in neuro-oncology, directly impacting patient survival rates and treatment efficacy. This paper presents a novel deep learning framework that integrates automated tumor classification, grade prediction, and interactive patient engagement through an end-to-end pipeline. Our approach leverages transfer learning with EfficientNetB0 architecture, implementing a dual-head neural network that simultaneously performs multi-class tumor classification (glioma, meningioma, pituitary, and non-tumor) and grade estimation through morphological feature analysis. The system employs advanced data augmentation strategies, adaptive learning rate scheduling, and dropout regularization to achieve robust generalization. Experimental evaluation on a combined dataset of 7,023 MRI scans demonstrates superior performance with 98.2% classification accuracy, surpassing existing state-of-the-art methods by 2.4%. The precision-recall analysis reveals consistently high F1-scores across all tumor categories (> 0.96), with particularly strong performance in glioma detection (0.99 precision). Additionally, our novel threshold-based grading algorithm, utilizing segmented tumor area quantification, provides clinically relevant grade predictions with 89% concordance with radiologist assessments. The framework's modular architecture facilitates seamless clinical integration while maintaining computational efficiency (4.0M parameters, 15ms inference time), making it suitable for real-time diagnostic support in resource-constrained environments.

Index Terms—Deep Learning, Brain Tumor Classification, Transfer Learning, EfficientNetB0, Medical Image Analysis, Convolutional Neural Networks, Grade Prediction, Computer-Aided Diagnosis