NeuroGen: A Novel Generative Deep Learning Framework Utilizing CLIP-Guided Latent Diffusion for Enhanced Brain Tumor Diagnosis

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Accurate classification of brain tumors is essential for effective patient treatment. In recent years, artificial intelligence has shown significant promise in improving medical diagnostics. Despite these AI models' notable success, their performance and effectiveness remain highly dependent on large, high-quality datasets. However, collecting sufficient high-quality medical images is resource-intensive, resulting in many medical datasets in practice that are insufficient for effective model training. To address this challenge, this study introduces NeuroGen, a novel generative deep-learning framework that leverages contrastive language-image pretraining (CLIP)-guided latent diffusion to synthesize MRI brain tumor scans. This study investigates whether NeuroGen can improve brain tumor classification accuracy in constrained MRI datasets, hypothesizing that NeuroGen's augmentation will enhance model performance. To replicate real-world clinical imaging challenges, a limited dataset was constructed for four major tumor classes: gliomas, pituitary tumors, meningiomas, and no tumors. The NeuroGen framework was then trained on samples from this dataset and extensively fine-tuned to generate synthetic MRI imaging to mitigate the dataset constraints. To assess the effectiveness of NeuroGen's generative augmentation, an EfficientNet-B0 convolutional neural network (CNN) was trained on two datasets: (1) the original constrained dataset and (2) the original dataset with the NeuroGen framework applied. Validation metrics indicated improvements in accuracy, precision, recall, and F1-score, with a 35.1% improvement in classification accuracy. These findings show NeuroGen's potential to advance neurological AI by improving model performance in data-constrained environments.

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