Research Proposal

Brain Tumor Classification, Analysis using vision transformers, and Progression Modeling Using MRI Scans and Generative AI

Brain tumors are one of the most challenging medical conditions, requiring precise diagnosis, treatment planning, and prognosis. While traditional imaging techniques such as MRI provide valuable insights, they lack the ability to predict how a tumor will evolve over time. Understanding tumor progression is critical for determining the best treatment strategies, assessing the risk of recurrence, and improving patient outcomes. With advancements in artificial intelligence, particularly in generative models, there is now an opportunity to leverage deep learning to synthesize realistic tumor growth patterns over time.

This research aims to tackle the challenges in brain tumor diagnosis, analysis, and progression modeling through the use of deep learning models, specifically the Vision Transformer (ViT) and Latent Diffusion Models (LDM), along with the BraTS 2020 dataset. The project seeks to develop a comprehensive pipeline that enables accurate classification of different tumor types from MRI images, followed by detailed analysis of tumor characteristics such as size, shape, and location. Additionally, the research will employ Generative AI techniques to simulate tumor progression over time, providing valuable insights into tumor behavior.

The first phase of the project focuses on tumor classification and analysis. The BraTS 2020 dataset, which contains multi-modal MRI scans (T1, T2, FLAIR, and DWI) and segmentation labels for different tumor types, will be used for training and evaluation. Preprocessing techniques such as skull stripping using HD-BET and MONAI, bias correction using N4ITK, and intensity normalization will be applied to the MRI images to enhance model performance. Augmentation strategies, including rotations, flips, and intensity variations, will further improve the generalization of the models.

For tumor classification, a Vision Transformer (ViT) model will be fine-tuned on the BraTS 2020 dataset. The ViT model will serve as the backbone for feature extraction, and the head of the model will be replaced with a classifier layer that outputs tumor type predictions. Additionally, a hybrid model called TransUNet, which combines ViT with a U-Net decoder, will be employed for tumor segmentation. This model will generate binary masks that outline the tumor regions, enabling precise tumor localization.

In the second phase of the project, the focus shifts to tumor progression modeling using Generative AI. The Latent Diffusion Model (LDM) will be used to synthesize tumor growth over a 12-month period, based on the initial tumor characteristics such as size, location, and type. The LDM will be conditioned on these features, as well as time embeddings, to generate synthetic MRI sequences that simulate how the tumor evolves over time. The model will be trained using longitudinal MRI data from the BraTS dataset, and in cases where real data is limited, synthetic data will be created by interpolating tumor features. The LDM will generate 12 synthetic MRI images corresponding to each month, demonstrating the growth or shrinkage of the tumor.

The final phase of the research involves automating the generation of clinical reports. After the tumor classification, analysis, and progression modeling, the results will be compiled into a structured format and input into a reporting system. A LLM based model (Gemini or Llama-3) will be used to generate free-text summaries that provide clinical insights based on the tumor data. These reports will not only contain textual information but also include visual representations of the tumor, such as synthetic MRI images showing its growth over time.

The outcome of this research is expected to significantly improve the accuracy and efficiency of brain tumor diagnosis and monitoring. By automating the classification, analysis, and progression modeling of brain tumors, this system will save clinicians valuable time, reduce human error, and provide more reliable results. The synthetic tumor progression model will offer insights into how tumors grow and change over time, which could be beneficial for clinical decision-making, treatment planning, and clinical trials. Additionally, the automated report generation will ensure that clinicians have detailed and consistent reports, with both quantitative analysis and qualitative insights, ready for review and further action.

In conclusion, this research aims to integrate state-of-the-art deep learning techniques with Generative AI to develop a comprehensive system for brain tumor classification, analysis, and progression modeling. The combination of tumor classification, size and shape analysis, synthetic tumor growth modeling, and automated clinical reporting will provide a powerful tool for clinicians, ultimately improving patient outcomes and enhancing clinical decision-making. This project has the potential to revolutionize the way brain tumors are diagnosed, analyzed, and monitored, making it an important step toward more efficient and accurate healthcare.

References

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