# Synthesizing Missing MRI Modalities for Brain Tumor Segmentation

## 1 Introduction

As Mathematics and Computer Science students, we initially lacked familiarity with medical terminology. Therefore, we began by understanding the medical context of brain tumors [1].

Brain tumors arise due to abnormal and uncontrolled cell growth within brain tissue. Tumors may occur in nerves, the pituitary gland, pineal gland, or brain membranes, and cancer may also metastasize to the brain from other organs [2].

Because survival rates are often low, early and accurate detection is critical. Medical imaging plays a central role in diagnosis, and Magnetic Resonance Imaging (MRI) is considered the primary imaging modality [2].

The four most common MRI modalities are [3]:

- T1-weighted
- T1-weighted contrast-enhanced (T1ce)
- T2-weighted
- FLAIR (Fluid Attenuated Inversion Recovery)

Each modality provides complementary anatomical information. However, acquiring all modalities is challenging due to motion artifacts, time limitations, or contraindications to contrast agents, resulting in missing modalities that reduce segmentation performance [2].

This project aims to synthesize missing MRI modalities using deep learning techniques to enable reliable segmentation systems [1].

## 2 Methodology

The project follows a three-stage pipeline [1]:

1. **Preprocessing:** Standardization and augmentation of multimodal BraTS MRI data by simulating missing modalities [3].
2. **Model Implementation:** Adaptation of a U-Net architecture for modality synthesis and image translation [2].

3. **Downstream Validation:** Comparison of Dice and Jaccard metrics between segmentation results using synthesized data and complete real data [2].

**Keywords:** Deep Learning, MRI Modality Synthesis, U-Net, Brain Tumor Segmentation, Conditional Generative Models, Image Reconstruction.

# 3 Brain Tumor Detection vs Segmentation

Brain tumor analysis involves two major tasks:

- **Tumor Detection:** A classification task determining whether cancer exists.
- **Tumor Segmentation:** A pixel-wise labeling task identifying tumor regions.

This distinction is widely discussed in medical imaging literature [2]. This project focuses on enabling segmentation under incomplete imaging conditions by reconstructing missing MRI modalities [1].

# 4 Deep Learning in Brain Tumor Segmentation

Traditional approaches relied on thresholding, morphology, and clustering methods. Modern medical image analysis is dominated by deep learning approaches [2].

## 4.1 Convolutional Neural Networks (CNN)

CNNs automatically learn hierarchical image features where early layers capture edges and gradients while deeper layers learn semantic representations [2]. Architectures such as AlexNet and InceptionNet demonstrate effective convolutional feature learning.

## 4.2 U-Net Architecture

U-Net is one of the most influential architectures for medical image segmentation [2].

It consists of:

- Contracting path (encoder) for feature extraction
- Expanding path (decoder) for reconstruction
- Skip connections preserving spatial information

This design enables accurate pixel-level prediction required for medical segmentation tasks.

# 5 Expected Outcomes

Expected deliverables include [1]:

- A trained model capable of synthesizing missing MRI sequences.
- Evaluation using PSNR and reconstruction quality metrics.
- Validation comparing segmentation accuracy using real versus synthesized modalities.

Upcoming work includes dataset exploration, preprocessing, and baseline U-Net implementation.

# 6 Conclusion

Brain tumor segmentation heavily depends on multimodal MRI data, yet clinical constraints frequently produce incomplete imaging data [2]. Synthesizing missing MRI modalities can maintain segmentation performance and improve robustness of automated systems [2].

# References


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