Chapter 5
Advances in Brain Tumor Diagnosis Through Multimodal Imaging and Deep Learning Techniques

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ABSTRACT

Brain tumors represent abnormal growths of cells—either benign or malignant—within the confined space of the human skull. These growths can lead to severe health complications and long-term psychological and physical consequences, greatly diminishing a patient's quality of life. The survival rate for individuals diagnosed with malignant brain tumors decreases significantly over time if early interventions are not implemented. This study investigates advanced hybrid architectures, namely CNN-UNet, ResNet-UNet, EfficientNet-UNet, and EfficientNet integrated with Vision Transformers. A comprehensive comparative analysis of these hybrid architectures is conducted to recognize the most efficient model. The results

DOI: 10.4018/979-8-3373-4312-9.ch005

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indicate that EfficientNet-UNet architecture achieved superior performance on the BraTS dataset with an accuracy of 99.47%, while EfficientNet-Vision Transformer on the Nickparvar dataset from Kaggle reached an accuracy of 97%. These findings highlight the efficiency of advanced hybrid deep learning models in detecting brain tumors from multimodal MRI images.

I. INTRODUCTION

Brain tumors are the leading cause of cancers deaths worldwide; in adults they arise due to the uncontrolled division of cells. The brain is an essential organ composed of neuronal cells, along with supporting tissues such as cells known as glial cells and meninges that surround them (Azzarelli et al., 2018). Damage to these brain regions is permanent and may lead to severe illnesses, including possibly fatal brain tumors. Abnormal growth of cells in the human brain leads to the formation of certain cancers. The National Brain Tumor Society (NBTS) predicts that by 2025, around 18,330 fatalities will occur due to malignant brain tumors, and over 93,000 Americans will have been diagnosed of serious brain tumors. Several obstacles arise during patient treatment, since the survival rate for malignant brain tumors is 35.7%, according to a survey done over the last five years (National Brain Tumor Society, 2023). It is furthermore predicted that the death rate for males is 2.8 per 100,000 and for females it is 2.0 per 100,000, according to global age-standardized for primary malignant brain tumors (National Brain Tumor Society, 2023). Accurate and early detection and diagnosis play a significant role in preventing mortalities related to brain tumors (Grant et al., 2020). There exist several imaging modalities to capture the tumors such as magnetic resonance imaging (MRI), computed tomography (CT), X-rays, and Ultrasound and are used in medical diagnostics. MRI is considered a powerful and significant tool for screening brain cancers, as it offers enhanced visibility of surrounding soft tissue features (Hussain et al., 2022). Traditional clinical based diagnosis potentially causes inaccuracies and delays and sometimes falls short of revealing the complete complexity of tumor features. Physicians are often dependent on multiple magnetic resonance imaging (MRI) images to assess tumor growth, but this procedure can be extremely intensive laborious and vulnerable to human inaccuracies, still MRI is widely used for brain tumor categorization and detection (Martucci et al., 2023). Automated techniques with the use of Artificial Intelligence tools could accelerate tumor diagnosis, reduce the occurrence of false positives rates, and minimize waiting times. For improving the health of patients,

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