RADemics

Brain Tumor Detection and Segmentation Using Advanced Deep Learning Models

Saurabh Prashant Maske, S. Gunasekaran
Gopikabai Sitaram Gawande Mahavidyalaya
Umarkhed, V.S.B Engineering College

Brain Tumor Detection and Segmentation Using Advanced Deep Learning Models

[1]Saurabh Prashant Maske, Assistant Professor, Department of Computer Science, Gopikabai Sitaram Gawande Mahavidyalaya Umarkhed, District Yavatmal, Maharashtra, India. spmaske01@gmail.com

[2]S. Gunasekaran, Assistant Professor, Department of Computer Science and Engineering, V.S.B Engineering College, Karur, Tamil Nadu, India. gkarthikkumaran@gmail.com

Abstract

Accurate detection and precise segmentation of brain tumors play a crucial role in clinical diagnosis, treatment planning, and patient prognosis within neuro-oncology. Magnetic Resonance Imaging provides detailed visualization of intracranial structures and remains the primary imaging modality for identifying tumor regions and associated abnormalities. Manual interpretation of MRI scans demands extensive clinical expertise and introduces variability in tumor delineation, creating a need for automated computational approaches. Recent advancements in deep learning have significantly improved the capability of computer-aided diagnostic systems for medical image analysis. Convolutional neural networks, encoder–decoder architectures, and transformer-based frameworks enable effective extraction of hierarchical spatial features from complex brain imaging data. Integration of hybrid deep learning models combining convolutional networks with attention-based transformers enhances segmentation accuracy by capturing both local structural patterns and global contextual relationships. This chapter presents a comprehensive overview of advanced deep learning techniques, preprocessing strategies, multimodal MRI analysis, and evaluation methodologies for automated brain tumor detection and segmentation.

Keywords: Brain Tumor Detection, Medical Image Segmentation, Deep Learning, Convolutional Neural Networks, Transformer Networks, Magnetic Resonance Imaging.

Introduction

Brain tumors represent a major category of neurological disorders characterized by abnormal growth of cells within intracranial tissues [1]. Such tumors originate from various cellular components of the central nervous system, including glial cells, meninges, and endocrine tissues located within the cranial cavity [2]. Incidence of brain tumors continues to rise globally, creating significant challenges for healthcare systems and clinical specialists. Early identification of tumor presence and accurate assessment of tumor boundaries play an essential role in determining appropriate therapeutic strategies and predicting patient prognosis [3]. Brain tumors frequently demonstrate complex structural characteristics that involve heterogeneous tissue composition, irregular boundaries, and infiltration into surrounding healthy brain regions [4]. These characteristics complicate accurate diagnosis and treatment planning. Clinical management of brain tumors relies heavily on imaging technologies that provide detailed visualization of intracranial structures [5]. Reliable detection methods therefore remain a crucial component of neurological research and clinical practice. Continuous development of advanced computational approaches for automated tumor analysis contributes toward improved diagnostic accuracy and efficient evaluation of medical imaging data.

Medical imaging technologies serve as essential diagnostic tools for identifying abnormalities within brain tissues [6]. Magnetic Resonance Imaging has become the most widely utilized imaging modality for brain tumor assessment due to superior soft tissue contrast and detailed visualization of anatomical structures [7]. MRI scans generate multiple imaging sequences that reveal distinct tissue characteristics and structural variations within the brain. Imaging modalities such as T1-weighted, T2-weighted, contrast-enhanced, and fluid-attenuated inversion recovery sequences provide complementary perspectives that support comprehensive tumor evaluation. Radiological interpretation of these images enables identification of tumor location, size, internal heterogeneity, and surrounding edema [8]. Traditional analysis of MRI images depends largely on manual examination performed by experienced radiologists and neurospecialists. Such manual procedures require considerable time and extensive clinical expertise [9]. Variability in interpretation across specialists introduces inconsistencies in tumor delineation and diagnostic conclusions. Automated analysis techniques capable of assisting radiological interpretation have therefore become an important area of investigation within medical imaging research [10].