Automated Brain Tumor Detection and Classification Using Deep Learning with Stack LSTM

Muskan J Momin
Department of Information technology
Pimpri-Chinchwad College of Engineering
Pune, India
muskanmomin@gmail.com

Sandhya S Waghere
Department of Information technology
Pimpri-Chinchwad College of Engineering
Pune, India
sandhya.shinde@pccoepune.org

***Abstract*— Brain tumors are one of the most common and aggressive diseases, often leading to a significantly reduced life expectancy, particularly in their highest grade. Therefore, treatment planning plays a critical role in improving the quality of life for patients. Various imaging techniques, such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and ultrasound, are commonly used to evaluate tumors in organs like the brain, lungs, liver, breast, and prostate. This study specifically focuses on the use of MRI images for brain tumor diagnosis. However, the vast amount of data generated by MRI scans makes manual tumor classification both time-consuming and error prone. Traditional methods also have limitations in providing accurate quantitative measurements for a limited number of images. Consequently, there is an urgent need for trusted and automated classification systems to reduce the death rate associated with brain tumors. The task of automatic brain tumor classification is challenging due to the large spatial and structural variability in the regions surrounding brain tumors. In this work, we propose an advanced brain tumor detection system using Deep Learning techniques, particularly leveraging a Stack Long Short-Term Memory (LSTM) network. This method is designed to handle the complexities of brain tumor images by capturing both spatial and temporal patterns, which significantly improves the classification accuracy. Once a tumor is detected, the system classifies it into specific categories, such as benign or malignant, and estimates the likely stage of the tumor. This approach offers a reliable, automated solution to enhance early detection and assist in timely treatment planning.**

Keywords*— *Brain Tumors, Treatment Planning, Imaging Techniques, MRI images, Deep Learning, Stack LSTM.

I. Introduction

Brain tumors are abnormal growths of cells in the brain, and they represent one of the most critical health conditions affecting humans. A brain tumor develops from the uncontrolled division of cells, leading to a mass of tissue known as a tumor. Tumors are classified into two primary categories based on their grade: low-grade tumors (Grade 1 and Grade 2), which are benign, and high-grade tumors (Grade 3 and Grade 4), which are malignant. Benign tumors are non-cancerous and do not spread to other parts of the brain, whereas malignant tumors are cancerous and tend to spread rapidly to other regions of the brain and body, often leading to severe consequences, including death.

Magnetic Resonance Imaging (MRI) is one of the most effective imaging techniques for detecting brain tumors and modelling their progression. Compared to other imaging methods such as Computed Tomography (CT) or ultrasound, MRI provides more detailed information regarding brain structure and can detect abnormalities in brain tissue. MRI scans are instrumental in both tumor detection and treatment planning.

Over the years, various automated methods have been developed for brain tumor detection and classification using MRI images. Among the traditional methods, Neural Networks (NN) and Support Vector Machines (SVM) have been popular due to their good performance in medical image analysis. However, with the advancement of technology, Deep Learning (DL) models have emerged as a revolutionary approach. DL models, particularly Convolutional Neural Networks (CNNs), have proven to be highly effective in recognizing complex patterns in medical images, eliminating the need for many nodes in comparison to earlier techniques like K-Nearest Neighbor (KNN) and SVM. As a result, Deep Learning has become a leading approach in areas such as medical image analysis, bioinformatics, and health informatics.

A brain tumor can either be primary, originating in the brain or adjacent tissues (such as the meninges, cranial nerves, or pituitary gland), or secondary, where cancer cells from other organs (e.g., lungs, kidneys, breast) spread to the brain. Primary brain tumors arise due to DNA mutations that cause abnormal cell growth. This uncontrolled growth can result in brain damage and, if untreated, can be life-threatening. Early detection and classification of brain tumors are crucial for timely intervention and improved patient outcomes. In this work, we propose a Deep Learning-based approach using Convolutional Neural Networks (CNN) integrated with Stack Long Short-Term Memory (LSTM) to automate brain tumor detection and classification with high accuracy, enabling early diagnosis and better treatment planning.

II. Literature Survey

[1] Siar et al. proposed a method to detect brain tumors by integrating deep neural networks with machine learning algorithms. Their approach utilized deep learning for automatic tumor identification from MRI scans, showcasing the transformative role of AI in medical diagnostics. The research demonstrated that combining deep learning with traditional machine learning techniques significantly improved the accuracy and efficiency of brain tumor detection, making it a promising tool for clinical use.

[2] Khan et al. introduced an intelligent brain tumor identification model employing deep learning techniques. The model leveraged advanced neural networks to enhance the accuracy of tumor detection from MRI images. Their work highlighted deep learning's ability to capture complex patterns and relationships in medical images, making it a powerful approach for automated tumor detection.

[3] Khan et al. focused on leveraging deep convolutional neural networks (CNNs) for precise brain tumor detection. The study demonstrated how CNNs effectively extracted features from MRI scans, achieving high accuracy in classifying brain tumors. This research emphasized CNNs' robustness and efficiency in medical imaging, providing a reliable method for automated tumor diagnosis.

[4] Amin et al. conducted a comprehensive survey on machine learning methods for brain tumor detection and classification. Their review included traditional algorithms and advanced deep learning models, exploring their applications to medical imaging. The study highlighted the strengths and limitations of various techniques, emphasizing the growing significance of deep learning in achieving accurate and reliable results.

[5] Soomro et al. reviewed image segmentation techniques for detecting brain tumors in MRI scans. The research focused on the role of machine learning in improving segmentation accuracy, which is critical for precise tumor localization. Their findings provided valuable insights into how segmentation methods enhance brain tumor detection through improved image analysis.

[6] Saeedi et al. proposed a brain tumor detection method based on convolutional deep learning techniques combined with traditional machine learning approaches. By analyzing MRI scans, their model improved detection accuracy by leveraging the strengths of both methods. The study demonstrated CNNs' efficacy in extracting complex features and their potential for advancing medical diagnostics.

[7] Amin et al. introduced a method for brain tumor detection using feature fusion and machine learning. Their approach integrated diverse features from MRI images, improving classification accuracy. By fusing multiple feature types, the model outperformed those relying on individual features, offering a more robust solution for tumor detection.

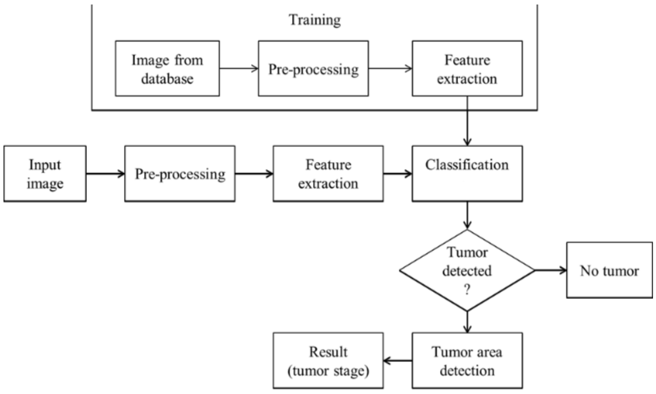
[8] Kumar et al. developed a brain tumor diagnosis model that combined image fusion with deep learning. By integrating MRI and CT imaging modalities, their approach provided a comprehensive view of the tumor, enhancing detection and classification accuracy. The study highlighted the benefits of image fusion in delivering more reliable diagnostic outcomes.

[9] Woźniak et al. introduced a deep neural network-based correlation learning mechanism for detecting brain tumors from CT scans. Their method demonstrated how neural networks could complement MRI-based techniques, improving the efficiency and accuracy of tumor detection using CT images.

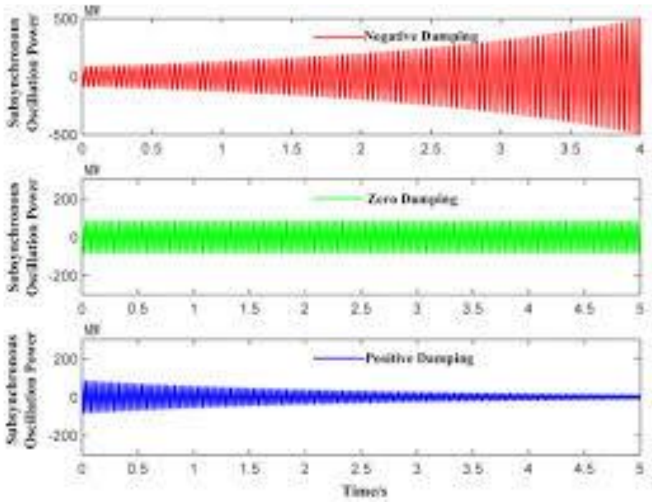
[10] Aamir et al. designed a deep learning model for brain tumor classification using MRI images. Their approach classified tumors into categories, such as benign and malignant, with high accuracy. The study showcased deep learning's effectiveness in tumor classification, providing a reliable tool for automated diagnosis in clinical practice.

III. METHODOLOGY

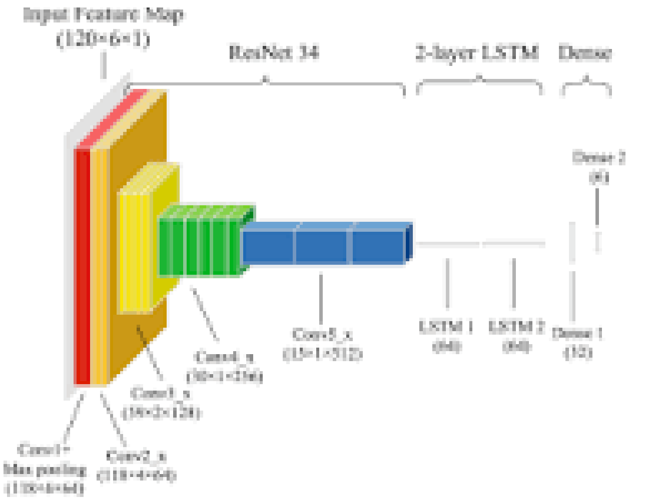
The methodology for brain tumor detection utilizes a Stacked Long Short-Term Memory (LSTM) neural network to automate the process of tumor detection and classification from medical images. The methodology is divided into two main phases: training and testing. In the training phase, a labeled data set of medical images, typically MRI scans, is collected. The data set is categorized into two classes: "tumor" and "no tumor," with annotations for the tumor stages. The images undergo a series of preprocessing steps, including resizing, normalization, and augmentation.



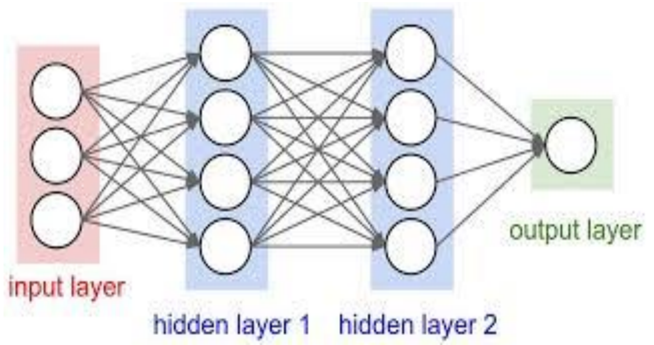
These steps ensure uniform image dimensions and introduce variability, which enhances the model's ability to generalize across different patient cases and tumor types. Instead of relying on traditional handcrafted feature extraction, the Stacked LSTM model is employed to automatically learn spatial and temporal features from the images. The images are divided into sequences of patches or spatial regions, which are sequentially fed into the LSTM layers. The multiple layers of the Stacked LSTM enable the model to capture complex patterns indicative of tumor presence.



During the testing phase, input images are preprocessed in the same way as the training images. The preprocessed image is passed through the trained Stacked LSTM model, which extracts features and classifies the image as either containing a tumor or not. If a tumor is detected, a post-processing step is performed to localize the tumor area within the image. This step may involve generating a heat map overlay or applying segmentation techniques to highlight the affected region.



Additionally, the model estimates the tumor stage, providing valuable diagnostic information that can assist in determining the appropriate course of medical intervention. By leveraging the sequential learning capability of Stacked LSTMs, this approach aims to improve the accuracy of tumor detection, enable precise localization of the tumor, and provide reliable tumor stage classification. The use of augmented data during training enhances the model's robustness and generalizability, ensuring its applicability across a wide range of patient cases and tumor types. This automated system offers an efficient and reliable tool for assisting clinicians in diagnosing and monitoring brain tumor patients.



IV. RESULTS AND DISCUSSION

1. **High Accuracy in Tumor Detection**: The use of a Stacked LSTM for sequential feature extraction and classification can lead to improved detection accuracy due to its ability to learn complex patterns within spatial sequences of images.
2. **Tumor Localization:** For detected tumors, the model is expected to highlight the tumor area, which aids in visualization and further diagnosis. The segmented area should correlate with the actual tumor boundary.
3. **Tumor Stage Classification:** Based on learned features, the model will provide an estimated tumor stage, which helps in understanding the severity and progression. This output can assist medical professionals in determining appropriate treatment plans.
4. **Generalization across Different Cases:** By training the model on a diverse data set and employing augmentation in the preprocessing steps, the Stacked LSTM should generalize well across different types of tumors and patient data.

In summary, the Stacked LSTM methodology enables a structured approach to detecting tumors with an additional focus on localization and stage classification, enhancing the overall effectiveness of the diagnostic process in medical imaging.

V. APPLICATION

1. **Early Detection of Tumors:** The system assists in identifying tumors at an early stage by detecting subtle patterns in medical images, potentially improving patient outcomes through timely intervention.
2. **Automated Tumor Staging:** By classifying detected tumors into different stages, the system aids doctors in determining disease severity, which is crucial for developing targeted treatment plans and predicting prognosis.
3. **Precise Tumor Localization:** The model highlights tumor regions within images, allowing for more accurate targeting in treatments like radiation therapy. This precision helps minimize damage to surrounding healthy tissues.
4. **Efficient Screening and Triage:** In high-volume medical facilities, the system can screen large numbers of images, prioritizing those with potential abnormalities for further review, thereby optimizing radiologist workflows and reducing diagnostic delays.
5. **Clinical Decision Support:** Serving as a second opinion, this tool supports radiologists and oncologists in making diagnostic and treatment decisions, especially in complex or borderline cases.
6. **Remote Diagnosis in Telemedicine:** The system can be used for remote tumor analysis, making advanced diagnostics accessible in under-resourced or rural areas and expanding healthcare reach.

VI. CONCLUSION

The proposed automated brain tumor detection and classification system using Deep Learning techniques, particularly the Stack Long Short-Term Memory (LSTM) network, represents a significant breakthrough in medical imaging. By addressing the challenges of spatial and structural variability in brain tumors, the system provides an efficient and accurate solution for early diagnosis. Its ability to process and analyze the extensive data generated by MRI scans ensures precise detection, classification, and staging of brain tumors, distinguishing between benign and malignant cases with improved accuracy. This system reduces reliance on manual interpretation, overcoming the limitations of traditional methods that are often time-intensive and prone to inconsistencies. By automating tumor analysis, it supports clinicians with reliable diagnostic insights, enabling timely and effective treatment planning. The proposed solution not only enhances diagnostic accuracy but also contributes to improved patient care by facilitating early interventions, potentially reducing mortality rates. Integrating such advanced AI-based systems into clinical workflows can revolutionize healthcare delivery and set new standards for brain tumor diagnosis and treatment.

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