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Review on MRI Image based Brain Tumor Detection and Prediction using Machine Learning

[1]Lavkush Nagle, [2]Prof. Ayush Kumar
M. Tech. Scholar, Department of Computer Science and Engineering, Radharaman Engineering College, Bhopal[1]
Assistant Professor, Department of Computer Science and Engineering, Radharaman Engineering College, Bhopal[2]

Abstract
Brain tumors are one of the most critical neurological disorders, and their early detection and accurate classification play an important role in improving patient diagnosis and treatment outcomes. Magnetic Resonance Imaging (MRI) is widely used for brain tumor identification because it provides detailed information about brain tissues and abnormalities without using ionizing radiation. However, manual examination of MRI images by radiologists can be time-consuming and may lead to variations in diagnostic accuracy. Machine Learning (ML) techniques have emerged as effective approaches for automated brain tumor detection and prediction by identifying important patterns and features from MRI images. This review presents a comprehensive study of MRI image-based brain tumor detection and prediction using various machine learning and deep learning techniques. It investigates different image preprocessing methods, including noise removal, image enhancement, skull stripping, segmentation, and feature extraction, to improve the quality of MRI images. Furthermore, various classification algorithms, such as Support Vector Machine (SVM), K-Nearest Neighbors (KNN), Random Forest (RF), Decision Tree (DT), and Artificial Neural Networks (ANN), are reviewed. These techniques are analyzed based on their performance using evaluation metrics such as accuracy, precision, recall, F1-score, sensitivity, and specificity. The review also discusses the major challenges associated with existing approaches, including limited medical datasets, class imbalance, image variability, computational complexity, and model generalization. Finally, this study identifies research gaps and future opportunities for developing intelligent, reliable, and computationally efficient MRI-based brain tumor detection and prediction systems to support early diagnosis and clinical decision-making.

Keywords: - MRI Brain Image, Machine Learning, Brain Tumor, Detection

1. INTRODUCTION

In the current society, the people living on the earth are being troubled with several diseases. Based on the statistics, 1/2th of humans are harmed by diseases and have medicines in an unavoidable situation for their survival. The doctors and the hospitals are increasing day by day and each day brings a new disease [1]. To handle these kinds of diseases, doctors need some special automation tools for prediction and to make their tasks easier. To enhance the advanced prediction based on a patient's care, medical innovation is to be enhanced in the

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form of automated tools. This is essential to improve the efficiency of doctors/technicians and also to minimize the death rate and reduce the suffering of the patient. Based on the estimation of the World Health Organization (WHO), cancer was the second foremost mortality caused in people all around the world. The most cancer-affected people are under 70 years of age in the year 2015. Population growth, ageing, economic development, and change in lifestyle are the reasons for these cancer occurrences [2]. Brain cancer/tumor is the most significant disease that has risen vigorously in recent decades in the world. Malignant is one type of brain tumor that is caused rarely for adults in 1–2%. Based on the GLOBOCAN 2012, the survival rate of brain cancer is minimum and it impacts people's quality of life, mortality rate, and economic costs.

The brain tumor is developed by several factors to ionizing radiation, cyclic aromatic hydrocarbons, pesticides, etc. Socioeconomic and environmental factors are the main reasons behind brain cancer mortality. Brain tumor is rectified around the world by preventing causative factors, improved medical care, and enhanced diagnostic methods in different countries [3, 4].

In the present decades, tumor/cancers are life-threatening diseases that involved an abnormal proliferation of cells [5]. These diseases are originated from one cell that provides various characteristics in the body named as hallmarks of tumor. Generally, the tumor cells can replicate autonomously and naturally. It can attack other tissues and affect the natural function of the working cell. The capacity of attacking nearby tissues and spreading to metastasis areas (distant sites of the body) differentiates malignant tumors (cancers) from benign tumors. Every year, approximately nine million people in the world die due to various types of brain tumor. The brain tumors established a heterogeneous set of tumors that are connected with variable behaviors, origins, symptoms, and malignancy. The tumor is classified by the type of cell from which it arises. The gliomas are nothing but tumor that is raised from a glial cell. Based on the World Health Organisation (WHO), Gliomas are categorized into 4 grades of malignancy.

Brain tumors are classified into several types, the most common of which are primary and secondary tumors. These tumors are developed within the brain region. Many of the brain tumors are the second type that is corresponding to metastases of primary type cancers [6, 7]. The secondary type tumors occur outside the brain generally like lung cancer. The common types of primary brain tumors are gliomas and meningiomas. As we know Gliomas start from a glial cell that is the main component of the nervous tissue (with neurons). The Meningiomas tumor is a tumor starting from a membrane that is used to protect the brain and the spinal cord. Many tumors are benign and can be cured by surgery if it is necessary.

2. LITERATURE REVIEW

Kodipalli et al. [1], study focused on comparing different machine learning algorithms for improving the accuracy of brain tumor detection using MRI images. The authors investigated the performance of various classification techniques to identify brain tumor patterns and distinguish between tumor and non-tumor cases. The comparative analysis highlighted the importance of selecting suitable machine learning models for achieving reliable classification

performance. However, the study indicated the need for further improvements in feature extraction, model optimization, and classification accuracy to develop more efficient brain tumor detection systems.

M. Revathi et al. [2], study focused on improving brain tumor detection accuracy by integrating Fuzzy C-Means (FCM) segmentation with the Support Vector Machine (SVM) classification algorithm. Fuzzy C-Means was utilized to segment important regions from MRI images, while SVM was employed to classify the extracted features for brain tumor identification. The combination of segmentation and machine learning techniques aimed to improve the detection and classification process. However, the approach may require further optimization to handle complex tumor structures, variations in MRI image quality, and different tumor categories.

A. Gulhane et al. [3], research investigated the design and performance analysis of machine learning-based approaches for detecting brain tumors from medical images. The study emphasized the application of intelligent classification techniques to improve the identification of abnormal brain tissues and enhance diagnostic performance. It also highlighted the importance of analyzing different machine learning techniques for developing accurate and efficient brain tumor detection systems. However, further research is required to improve feature selection, computational efficiency, and model generalization for reliable detection across diverse MRI datasets.

A B Malarvizhi et al. [4], a brain tumor is one of the leading causes of death among other types of cancer because it is formed by the gradual addition of abnormal cells. In order to treat a brain tumor, it is necessary to classify it using an MRI brain tumor image because MRI images help to detect even the smallest body defect. This paper intended to naturally characterize mind cancers utilizing an AI calculation. In this work, the information picture of the cerebrum was pre-handled utilizing middle channel, portioned from the foundation utilizing thresholding and K-implies grouping calculation and its elements were extricated utilizing GLCM. Utilizing the SVM classifier, the mind growth in the picture was identified as either harmless or threatening. This picture order process helps the specialists and examination researchers to identify the growth during its beginning phases, subsequently controlling the spread of carcinogenic cells.

Muhammad Arif et al. [5], radiology is an expansive subject that needs more information and comprehension of clinical science to precisely distinguish growths. The requirement for a growth identification program, consequently, beats the absence of qualified radiologists. Utilizing attractive reverberation imaging, biomedical picture handling makes it simpler to recognize and find cerebrum growths. Using images from the MRI sequence as an input image to identify the tumor area, this study developed a method for brain tumor segmentation and detection. This cycle is troublesome because of the wide assortment of growth tissues within the sight of various patients, and, much of the time, the comparability inside ordinary tissues makes the undertaking troublesome. The fundamental objective is to characterize the cerebrum within the sight of a mind cancer or a sound mind. The proposed framework has been explored in view of Berkeley's wavelet change (BWT) and profound learning classifier

to further develop execution and improve on the course of clinical picture division. The gray-level-co-occurrence matrix (GLCM) method is used to extract significant features from each segmented tissue, and then a genetic algorithm is used to optimize those features. The imaginative eventual outcome of the methodology carried out was surveyed in light of exactness, responsiveness, explicitness, coefficient of dice, Jaccard's coefficient, spatial cross-over, AVME, and FoM.

Munagalapalli Thanuj et al. [6], diagnosing a cerebrum cancer consumes most of the day and depends intensely on the radiologist's capacities and experience. How much information that should be dealt with has expanded decisively as the quantity of patients has expanded, making old methods both expensive and insufficient. Numerous scientists explored different calculations for recognizing and characterizing cerebrum growths that were both precise and quick. When it comes to creating automated systems that are able to accurately diagnose or segment brain tumors in a shorter amount of time, deep learning (DL) approaches have recently gained popularity. DL empowers a pre-prepared Convolutional Brain Organization (CNN) model for clinical pictures, explicitly for characterizing mind tumors. The proposed Mind Growth Characterization Model in light of CNN (BCM-CNN) is a CNN hyperparameters enhancement utilizing a versatile powerful sine-cosine wellness dark wolf enhancer (ADSCFGWO) calculation. There is an enhancement of hyperparameters followed by a preparation model worked with Commencement ResnetV2. The model utilizes usually utilized pre-prepared models (Commencement ResnetV2) to further develop cerebrum cancer conclusion, and its result is a twofold 0 or 1 (0: 1: Normal Tumor). There are fundamentally two sorts of hyperparameters: (i) hyperparameters that decide the hidden organization structure; (ii) a hyperparameter that is liable for preparing the organization. The ADSCFGWO calculation draws from both the sine cosine and dark wolf calculations in a versatile structure that utilizes the two calculations' assets. The trial results show that the BCM-CNN as a classifier accomplished the best outcomes because of the improvement of the CNN's presentation by the CNN enhancement's hyperparameters. The BCM-CNN has accomplished 99.98% precision with the Rascals 2021 Errand 1 dataset.

Nikita Mahajan et al. [7], a cerebrum cancer is a problem brought about by the development of unusual synapses. The endurance pace of a patient impacted with a growth is challenging to decide on the grounds that they are rare and show up in different structures. Magnetic Resonance (MRI) images can be used to identify these tumors and help locate the tumor's location; in any case, manual location is a tedious and testing technique that can cause a few mistakes in results. The reception of PC helped approaches is fundamental to help in defeating these requirements. With the progression of man-made consciousness, profound learning (DL) models are being utilized in clinical imaging to analyze mind cancers utilizing MR pictures. In this review, a profound convolutional brain organization (CNN) EfficientNet-B0 base model is adjusted with our proposed layers to productively characterize and recognize cerebrum growth pictures. The picture improvement procedures are utilized by applying different channels to improve the nature of the pictures. Information expansion techniques are applied to increment the information tests for better preparation of our

proposed model. The outcomes show that the proposed adjusted cutting edge EfficientNet-B0 outflanks other CNN models by accomplishing the most elevated arrangement exactness, accuracy, review, and region under bend values outperforming other cutting edge models, with an generally precision of 98.87% concerning arrangement and recognition. Other DL calculations like VGG16, InceptionV3, Xception, ResNet50, and InceptionResNetV2 are utilized for relative examination.

S. Karpakam et al. [8], a mind cancer is the development of synapses that are strange, some of which might advance into disease. The most common method for detecting brain tumors is a magnetic resonance imaging (MRI) scan. The cerebrum's strange tissue development should be visible on the X-ray pictures, which uncover. Profound learning and AI strategies are utilized to distinguish cerebrum growths in various exploration distributions. It just takes an exceptionally short measure of time to foresee a mind cancer when these calculations are applied to X-ray pictures, and the expanded precision simplifies patient therapy. The radiologist is able to quickly make decisions thanks to these forecasts. Deep learning, a convolution neural network (CNN), an artificial neural network (ANN), a self-defined neural network, and the existence of a brain tumor are utilized in the proposed strategy.

Monisha Barakala et al. [9], the humanoid system's most important component is the human brain. Mind cancers are brought about by cells that develop and isolate in the cerebrum in manners that shouldn't. As mind cancers develop, they can transform into cerebrum disease. PC vision is vital to human wellbeing since it removes the requirement for individuals to pursue precise choices. The most common and safest ways to get an image using magnetic resonance imaging (MRI) are CT scans, X-rays, and MRI scans. Small things can be found using MRI. We want to discuss the various ways that brain MRI can be used to find brain cancer in our paper. In this study, we removed noises from an MR image prior to processing with the bilateral filter (BF). The binary thresholding and Convolution Neural Network (CNN) segmentation methods were then used to locate the tumor region. Training datasets, test datasets, and validation datasets are all available. Our machine will be able to determine whether or not the subject has a brain tumor. A few proportions of execution, like exactness, responsiveness, and particularity, will be utilized to check the outcomes out. These thick layers separate highlights and all elements are passed to a completely associated layer. Brain MRI features are extracted more effectively by dense networks. Because MRI provides additional details about the structure and functions of cells, this work is conducted using MRI. It is hoped that the proposed work will perform better than other works of a similar nature.

N. N P. Patil et al. [10], the idea behind the proposed work is to use image segmentation to automatically detect autism. CNN is the most remarkable strategy for biomedical picture division where a few variations are proposed. The modified UNet segmentation method for image segmentation and classification known as Alpha-Beta Pruned UNet, which is a UNet dimensionality reduction technique, is the primary focus of the proposed work. Along with the results of the experiments, a metric is also used to compare UNet and the proposed algorithm.

Fatih Ozyurta et al. [11], one of the recent hot topics is super-resolution, which raises the resolution of images to new heights. A brain magnetic resonance image (MRI)'s important information is made more visible and clear by increasing the image's resolution in terms of the information it contains. As a result, the associated image's tumor borders will be more easily identified. Brain tumor detection using super-resolution convolutional neural networks and extreme learning machine algorithms (SR-FCM-CNN) has been proposed in this study. Using the Super Resolution Fuzzy-C-Means (SR-FCM) method for tumor detection from brain MR images, this study aimed to efficiently segment tumors. Following that, extreme learning machine (ELM) classification and feature extraction using the pretrained SqueezeNet architecture from convolutional neural network (CNN) architectures were carried out. In the trial studies, it has been resolved that mind cancers have been exceptional divided and eliminated utilizing SR-FCM technique. A smaller, with fewer parameters, neural network model was used to extract features using the SqueezeeNet architecture. Using SR-FCM, a diagnosis of segmented brain tumors has been made with an accuracy rate of 98.33% using the proposed approach. This rate is more prominent 10% than the pace of acknowledgment of mind growths portioned with fluffy C-implies (FCM) without SR.

A. M. Hasan et al. [12], advances in the space of man-made reasoning, AI, and clinical imaging innovations have permitted the improvement of the clinical picture handling field for certain shocking outcomes over the most recent twenty years. These developments empowered the clinicians to see the human body in high-goal or three-layered cross-sectional cuts, which brought about an expansion in the precision of the conclusion and the assessment of patients in a harmless way. The ability of magnetic resonance imaging (MRI) brain scan classifiers to extract meaningful features is the fundamental step. Accordingly, many works have proposed various strategies for highlights extraction to order the unusual developments in the mind X-ray examines. In recent times, the application of deep learning algorithms to medical imaging has resulted in remarkable performance gains in the classification and diagnosis of complex pathologies like brain tumors. In this paper, a profound learning highlight extraction calculation is proposed to extricate the pertinent elements from X-ray mind examines. The modified gray level co-occurrence matrix (MGLCM) method is used to extract handcrafted features simultaneously. The support vector machine (SVM) is used as a classifier to enhance the MRI brain scan classification process by combining the extracted relevant features with handcrafted features. The acquired outcomes demonstrated that the mix of the profound learning approach and the high quality elements removed by MGLCM works on the precision of grouping of the SVM classifier up to 99.30%.

A. Gumaei et al. [13], classification of brain cancer is an essential step that relies on the physician's expertise and knowledge. In order to assist physicians and radiologists in identifying brain tumors, an automated tumor classification system is absolutely necessary. However, for appropriate treatments, the accuracy of current systems needs to be improved. In order to develop a method for accurately classifying brain tumors, we present a hybrid feature extraction and regularized extreme learning machine (RELM) approach. Preprocessing the brain images with a min-max normalization rule to increase contrast

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between brain regions and edges is the first step in this strategy. The features of the brain tumor are then extracted using a hybrid feature extraction strategy. Last but not least, a RELM is used to classify the kind of brain tumor. To assess and look at the proposed approach, a bunch of trials is directed on another public dataset of cerebrum pictures. The experiment's performance in terms of classification accuracy improved from 91.51 percent to 94.233% for the random holdout technique experiment, demonstrating that the method is more effective than the current state-of-the-art methods.

3. BRAIN TUMOR USING MACHINE LEARNING

The malignant and benign are two main categories of the brain tumor. The skull is pressurized to enlarge from inside in case of growth of any benign or malignant tumor. This tumor leads to cerebrum lesion and that could be dangerous to existence also. The brain tumor is divided into two kinds - primary or secondary. The tumor which happens in the cerebrum is known as primary brain cancer. Various gray matters are gentle. An optional cerebrum tumor is additionally metastatic mind tumor. This tumor starts because of spreading of disease cells spread in the cerebral matter as of an additional limb in which lung or bosom is included. The encephalon could start inside the brain or it spread to from the rest of the organs of anatomy. It can broaden to the cerebrum. The growth rate and the position of a brain tumor investigate its impacts on the function of nervous system. The kind of brain tumor and also its size and location have assisted in prescribing the treatment options of brain tumor.

MRI Image

The sample MR images for the present experiment are drawn from BraTS 2018 dataset. They are used to train and test the proposed algorithm. There are two hundred thirty three patients with 6,128 brain MRI slices in the dataset. They contain three types of brain tumors: pituitary, glioma, and meningioma. These slices are acquired from the secondary sources. These slices were generated using a T1-weighted MRI sequence with 512 × 512 size pixels and are manually segmented by three expert radiologists to identify the tumor region. Each tumor has several slices, which are: 2026 slices for pituitary tumor, 1582 slices for meningioma, and 3020 slices for glioma.

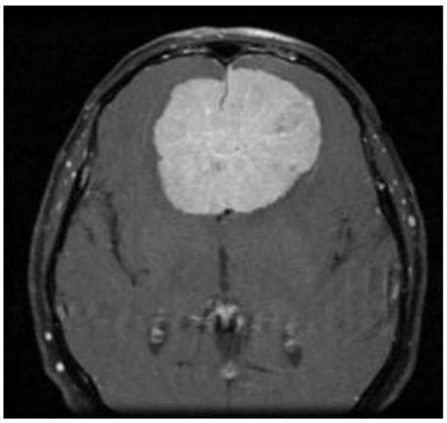

Figure 1: A sample MR image with meningioma

The dataset is partitioned into two: the training set contains 6,128 slices, in which 1,860 are

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related to pituitary, 1,416 are related to meningioma, and 2,852 are related to glioma. The testing dataset contains 166 slices for pituitary, 166 slices for meningioma, and 168 slices for glioma tumors. The following are a few sample images drawn from the two datasets with the three types of tumors as mentioned above. Figure 1 is the first sample MR image with meningioma. It is known that meningiomas are the most common form of brain tumors. It is understood that about 80% of these cases are considered Grade 1, which can generally be cured by surgery.

Figure 2 is the second sample MR image with glioma. It is a common type of tumor originating in the brain. It is understood that about 33% of all brain tumors are gliomas. They originate in the glial cells that surround and support neurons in the brain.

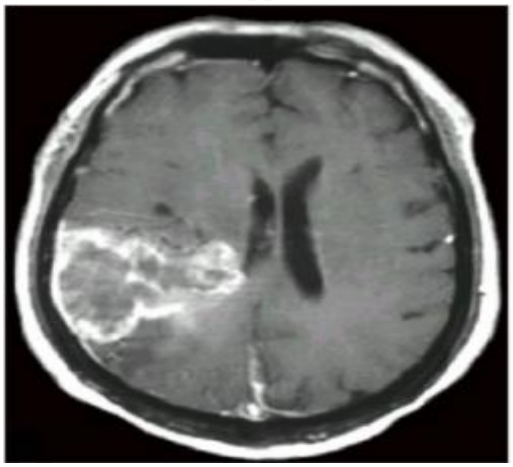

Figure 2: A sample MR image with glioma

The pituitary is often called the ‘master gland’. It controls the secretion of most of the hormones in the body. A normal pituitary gland weighs less than a gram. It is attached to the base of the brain and behind the nose. A large majority of pituitary tumors are benign. These tumors most commonly affect people in their 30s or 40s.

Figure 3 is the sample image with high-grade glioma. These are solid tumors and are highly malignant. They grow fast and frequently destroy healthy brain tissues. These high-grade gliomas in children and adolescents are rate. These have the potential of inducing the development of new tumors. The treatment is difficult due to their usually rapid and infiltrating growth.

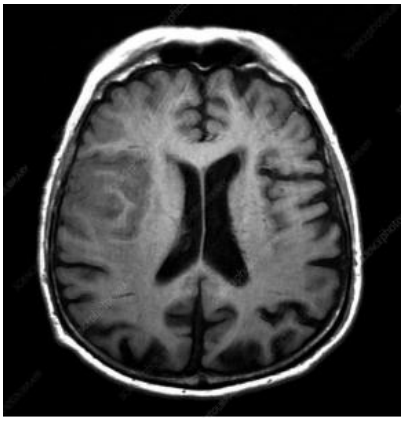

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Figure 3: A sample MR image with high-grade glioma

Figure 4 shows a sample MR image with low-grade glioma. It belongs to a diverse group of primary brain tumors. It often arises in young, otherwise healthy patients. It generally has an indolent course with longer-term survival in comparison with high-grade glioma.

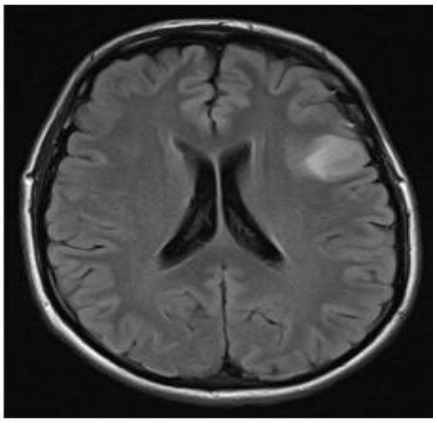

Figure 4: A sample MR image with low-grade glioma

Machine Learning

Machine Learning is a subset of Artificial Intelligence concerned with “teaching” computers how to act without being explicitly programmed for every possible scenario. The central concept in Machine Learning is developing algorithms that can self-learn by training on a massive number of inputs. Machine learning algorithms are used in various applications, such as email filtering and computer vision, where it is difficult or infeasible to develop conventional algorithms to perform the needed tasks [4]. Machine learning enables the analysis of vast amounts of information. While it usually delivers faster, more precise results to identify profitable prospects or dangerous risks, it may also require additional time and assets to train it appropriately. Merging machine learning with AI and perceptive technologies can make it even more effective in processing vast volumes of information. Machine learning is closely associated with computational statistics, which focuses on making predictions using computers. Machine learning approaches are conventionally divided into three broad categories, namely Supervised Learning, Unsupervised Learning & Semi-supervised Learning, depending on the nature of the "signal" or "feedback" available to the learning system.

Face anti-spoofing (FAS) has lately attracted increasing attention due to its vital role in securing face recognition systems from presentation attacks (PAs). As more and more realistic PAs with novel types spring up, traditional FAS methods based on handcrafted features become unreliable due to their limited representation capacity. With the emergence of large-scale academic datasets in the recent decade, machine learning based FAS achieve remarkable performance and dominate this area.

Supervised Learning

A model is trained through a process of learning in which predictions must be made and corrected if those predictions are wrong. The training process continues until a desired degree

of accuracy is reached on the training data. Input data is called training data and has a known spam / not-spam label or result at one time.

Unsupervised Learning

By deducting the structures present in the input data, a model is prepared. This may be for general rules to be extracted. It may be through a mathematical process that redundancy can be systematically reduced, or similar data can be organized. There is no labeling of input data, and there is no known result.

Semi-Supervised Learning

Semi-supervised learning fell between unsupervised learning (without any labeled training data) and supervised learning (with completely labeled training data). There is a desired problem of prediction, but the model needs to learn the structures and make predictions to organize the data. Input data is a combination of instances that are marked and unlabeled.

4. CONCLUSION

The review of MRI image-based brain tumor detection and prediction using machine learning techniques highlights the significant role of artificial intelligence in improving the accuracy and efficiency of brain tumor diagnosis. Various machine learning algorithms, including Support Vector Machine (SVM), Fuzzy C-Means (FCM), Random Forest, K-Nearest Neighbors (KNN), and other classification techniques, have demonstrated their potential for identifying and classifying brain tumors from MRI images. The reviewed studies indicate that image preprocessing, segmentation, feature extraction, and classification are essential stages in developing an effective detection system. However, existing approaches still face challenges related to image quality, dataset limitations, class imbalance, feature selection, computational complexity, and classification accuracy. Therefore, further research is required to develop optimized machine learning and deep learning models that provide better accuracy, reliability, and generalization. In the future, advanced CNN architectures integrated with optimization algorithms and effective image-processing techniques can be explored to improve brain tumor detection and classification. Such intelligent systems can support radiologists in early diagnosis, clinical decision-making, and improved patient care.

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