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A Survey on Brain Tumor Detection in Medical Image Processing

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ABSTRACT

Biomedical Image Processing is a dynamic and essential field encompassing various imaging modalities such as CT scans, X-rays, and MRI. These modalities play a crucial role in detecting subtle abnormalities within the human body. The primary objective of medical imaging is to derive accurate and meaningful information from these images while minimizing errors. Among the available imaging techniques, MRI stands out as a reliable and safe option, avoiding harmful radiation exposure. This paper focuses on the process of brain tumor detection using MRI, categorizing it into four key stages: Preprocessing, Segmentation, Optimization, and Feature Extraction. The survey consolidates insights from diverse research efforts, emphasizing the significance of each stage in the overall detection process. The compilation of research findings by various professionals provides a comprehensive overview of current methodologies, advancements, and challenges in brain tumor detection from MRI images. This survey aims to serve as a valuable resource for researchers and practitioners in the field of biomedical image processing.

1. INTRODUCTION

Intracranial neoplasms, commonly known as brain tumors, represent abnormal cell growth within the intricate and vital organ – the human brain. The manifestation of a brain tumor often presents with symptoms such as recurrent headaches and migraines, potentially progressing to vision loss over time. Despite advances in medical science, the origins and contributing factors to this abnormal growth remain elusive. Classified based on malignancy and origin, brain tumors are categorized as either benign or malignant. Benign tumors, characterized by slow growth and distinguishable features, pose a comparatively lower threat. Conversely, malignant tumors, with aggressive growth patterns, present a life-threatening challenge due to their elusive nature. Introduction:

Brain tumors, abnormal cell growth in the brain, present complex diagnostic challenges with symptoms like headaches. Classified as benign or malignant, these tumors require accurate detection. Magnetic Resonance Imaging (MRI) aids in detailed brain imaging, but Computerized Image Processing, utilizing segmentation and feature extraction, enhances precision for neurosurgeons in tumor detection.

For accurate tumor detection, medical practitioners employ diagnostic tools such as X-rays or Magnetic Resonance Imaging (MRI). MRI, harnessing the properties of magnetism and radio waves, emerges as a preferred choice, especially when conventional tests fall short in providing comprehensive information. Despite its effectiveness, MRI is unsuitable for individuals with pacemakers or metal implants due to its reliance on magnetic waves. Upon obtaining detailed brain images through MRI scans, precise detection of the tumor's size and location becomes imperative for neurosurgeons to formulate an accurate diagnosis. This critical stage is where Computerized Image Processing intervenes. Leveraging various segmentation techniques and feature extraction methods, this technology plays a pivotal role in enhancing the accuracy of tumor detection, facilitating informed decision-making for neurosurgeons.

2. KEY FINDINGS AND CONTRIBUTION

PAPER TITLE	MAIN CONTRIBUTION	KEY FINDINGS
An expert system for brain tumor detection : Fuzzy c-means with super resolution and convolutional neural network with extreme learning machine[1]	The SR-FCM-CNN approach, combining super-resolution with fuzzy clustering and convolutional neural networks for enhanced brain tumor detection	A 98.33% accuracy rate, demonstrating a 10% improvement over traditional fuzzy clustering methods without super-resolution
Optimizing MRI based brain tumor classification and detection using AI : A comparative analysis of neural networks, transfer learning, data augmentation and the cross – transformer network[2]	The proposal of a comprehensive framework utilizing state-of-the-art deep learning architectures, including a novel Cross-Transformer, for accurate brain tumor classification and detection	Achieving over 97% accuracy in tumor classification, and the effectiveness of learning transfer, data augmentation, and FLAIR sequence for improved detection, with the proposed model demonstrating superior efficiency in training time
A brain tumor detection system using gradient based watershed marked active contours and curvelet transform[3]	GWMAC-CT methodology, combining gradient-based watershed transform, improved active contours, and curvelet transform for efficient brain tumor detection in MR image.	Achieving a high accuracy of 96.81% with SVM classification, demonstrating the effectiveness of the proposed two-stage segmentation method and curvelet transform-based feature extraction
BrainMRNet : Brain tumor detection using magnetic resonance images with a novel convolutional neural network model[4]	The introduction of BrainMRNet, a novel convolutional neural network architecture incorporating attention modules and the hyper column technique for improved brain tumor detection	BrainMRNet outperforming pre-trained models (AlexNet, GoogleNet, VGG-16) with a classification success rate of 96.05%, showcasing its effectiveness in biomedical image analysis
Detection of tumors on brain MRI images using the hybrid convolutional neural network architecture[5]	The development of a CNN-based brain tumor diagnosis system, using a modified Resnet50 architecture with 97.2% accuracy	The proposed method's effectiveness, surpassing other CNN models (Alexnet, Densenet201, InceptionV3, Googlenet) and highlighting its potential for computer-aided brain tumor detection
Brain tumor detection using artificial convolutional neural networks[6]	The development of an Artificial Convolutional Neural Network model for brain tumor detection using MRI images, achieving excellent results with 96.7% accuracy on validation data and 88.25% on test data	The study emphasizes the efficacy of the neural network in analyzing and predicting the likelihood of brain tumors based on diverse image datasets
Optimized edge detection technique for brain tumor detection in MR images[7]	The proposal of an optimized edge detection technique using Genetic Algorithms, obtaining optimal filter coefficients and thresholding algorithms	Demonstrate superior performance in edge detection, particularly in brain tumor detection from MR scan images, surpassing classical and fractional-order methods based on qualitative and quantitative analyses
Convolutional neural network for brain tumor detection[8]	The utilization of Convolutional Neural Networks (CNN) for brain tumor classification in MRI images, aiming for early and efficient diagnosis	The comparison of two CNN models, leading to the identification of the best-performing model, achieving a notable prediction accuracy of up to 93%

Detection of brain tumors from MRI images base on deep learning using hybrid model CNN and NADE[9]	The development of a hybrid paradigm, combining neural autoregressive distribution estimation (NADE) and convolutional neural network (CNN), for efficient brain tumor detection using MRI images	The hybrid CNN-NADE model's high classification performance, especially in scenarios where the availability of medical images is limited, addressing the challenges associated with malignant brain tumors
Deep neural network correlation learning mechanism for CT brain tumor detection[10]	The introduction of a novel correlation learning mechanism (CLM) that enhances deep neural network architectures, combining convolutional neural network (CNN) with a classic architecture for more efficient evaluation of CT brain scans	The CLM model achieves approximately 96% accuracy, demonstrating improved learning speed and higher efficiency in comparison to traditional approaches.
A novel framework for brain tumor detection based on convolutional variational generative model[11]	The introduction of a novel framework for brain tumor detection, utilizing a generative model to synthesize a large, balanced MRI dataset, addressing limitations in data availability	Overall detection accuracy of 96.88%, showcasing the potential of the proposed framework as an accurate and low-overhead brain tumor detection system, particularly beneficial in the context of small class-unbalanced datasets
Brain tumor detection using fusion of hand crafted and deep learning features[12]	The integration of the GrabCut method for accurate lesion segmentation with a fine-tuned Transfer Learning model (VGG-19) and handcrafted features for efficient brain tumor diagnosis	Outstanding testing results, achieving high Dice Similarity Coefficients (DSC) of 0.99 on BRATS 2015, 1.00 on BRATS 2016, and 0.99 on BRATS 2017, showcasing the effectiveness of the proposed model
A comprehensive review on multi-organs tumor detection based on machine learning[13]	A comprehensive survey analyzing existing computer-aided systems for brain, breast, skin, and lung cancer/tumor detection across various modalities, emphasizing challenges such as poor contrast, complex background, and fuzzy borders	The effectiveness of computer vision and deep learning approaches in enhancing early-stage tumor detection in diverse medical imaging modalities
Learning methods of convolutional neural network combined with image feature extraction in brain tumor detection[14]	The development of a convolutional neural network (CNN) based model for brain tumor detection, leveraging MRI technology and feature fusion to enhance efficiency and recognition rates	The proposed algorithm demonstrates practical effectiveness, paving the way for potential applications in computer-aided brain tumor detection
MRI – based tumor detection using the fusion of histogram oriented gradients and neural features[15]	The development of an intelligent system for brain tumor identification, utilizing a fusion of histogram of oriented gradient and deep CNN-based neural features from MRI, enhanced through Principal Component Analysis and a Bootstrap Aggregation ensemble classifier	Reveal a satisfactory performance with a detection accuracy of 98.79%, demonstrating the effectiveness of the fusion-based approach on diverse MRI sequences from BRATS 2013 and BRATS 2015 datasets
Brain tumor detection in MR image using superpixels, principle component analysis and template based k-means clustering algorithm[16]	The introduction of an enhanced brain tumor detection scheme using template-based K-means with superpixels and principal component analysis, achieving higher accuracy	Improved accuracy and faster execution (in seconds) in detecting brain tumors through the proposed approach, addressing limitations of current methods in terms of accuracy and processing time

	and reduced execution time compared to existing schemes	
Detection and classification of brain tumor in MRI images using wavelet transform and support vector machine[17]	An analytical approach for brain tumor detection using noise reduction, gray-level co-occurrence matrix-based feature extraction, Discrete Wavelet Transform-based segmentation, and a Support Vector Machine classifier, achieving a high classification accuracy of 98.91%	The efficacy of the proposed system in enhancing performance, reducing complexity, and providing accurate brain tumor detection through the outlined processes
Brain tumor detection and classification using convolutional neural network and deep neural network[18]	The implementation of a deep neural network, specifically a CNN-based model, for accurate classification of brain MRIs into "TUMOUR DETECTED" or "TUMOUR NOT DETECTED," achieving a mean accuracy score of 96.08% and an impressive F-score of 97.3	The efficacy of the proposed computer-aided approach in achieving high accuracy and precision, surpassing traditional manual diagnosis practices
Brain tumor detection based on extreme learning[19]	The application of triangular fuzzy median filtering for image enhancement, coupled with Gabor and similar texture (ST) feature extraction, and extreme learning machine (ELM) for accurate segmentation and classification of gliomas in brain MRI	The proposed approach's superior results and reduced computational time when evaluated on challenging datasets, including BRATS 2012, 2013, 2014, 2015, and the 2013 Leaderboard
Brain tumor detection from MRI images using bag of features and deep neural network[20]	The utilization of advanced machine learning approaches, including Support Vector Machine (SVM) and Deep Neural Network (DNN), for improved brain tumor detection through a methodology involving feature extraction using Flexible Wavelet Transform and AlexNet.	The introduction of a Bag of Features (BoF) method for efficient feature selection, achieving high precision in brain tumor identification with the SVM classifier, and demonstrating enhanced accuracy and speed in publicly available MRI datasets

Fig. 1

3. TECHNIQUES AND ARCHITECTURE

Feature Extraction and Classification Framework:

The proposed methodology employs preprocessing techniques such as gray scale conversion, dataset resizing, and Bag of Features (BoF) for efficient feature selection. Utilizing Flexible Wavelet Transform (FWT) and AlexNet, the approach extracts both handcrafted and spatial features from MRI images, forming a single combined Feature Vector Table (CFV). Classification is achieved through K-Nearest Neighbor (KNN) and Support Vector Machine (SVM), with SVM exhibiting the highest precision in accurately identifying brain tumors[20]

Enhanced Brain Tumor Detection Scheme with TK-means Algorithm:

The proposed brain tumor detection scheme utilizes the template-based K-means (TK) algorithm, incorporating superpixels and principal component analysis (PCA). Essential features are extracted through superpixels and PCA, enhancing accuracy, and image enhancement is performed using a filter. The TK-means clustering algorithm is then employed for image segmentation, achieving improved accuracy and reduced execution time compared to existing schemes[16]

Synthetic MRI Data Generation for Improved Brain Tumor Detection:

The proposed brain tumor detection framework employs a novel approach by generating a synthetic MRI images dataset to address the challenge of limited class-balanced data. It utilizes a generative model to capture feature distributions in a small, unbalanced dataset and synthesize images for each class, creating a larger balanced dataset. A second model, the classifier, is then trained on this balanced dataset, achieving an overall detection accuracy of 96.88%, demonstrating the efficacy of the framework for accurate and low-overhead brain tumor detection[11]

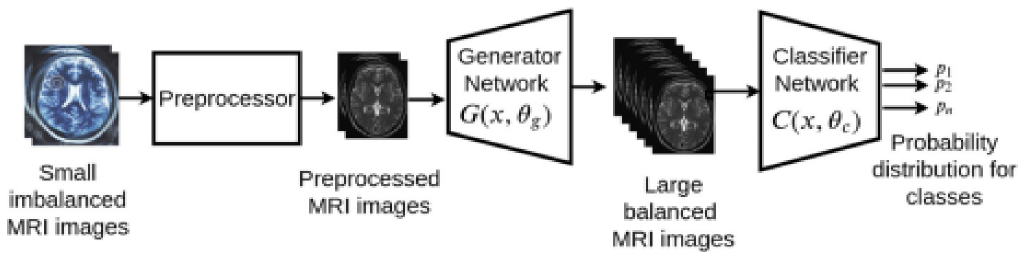

Fig.2. The proposed framework

Integrated CNN-MRI Computer-Aided Brain Tumor Detection Model:

The study proposes a computer-aided detection model for brain tumor detection by combining convolutional neural networks (CNN) with MRI technology. The model integrates convolutional layers to enhance recognition efficiency and incorporates feature fusion, combining artificially selected and machine learning features for improved diagnostic results. The designed algorithm demonstrates practical effects and offers theoretical references for future research in computer-aided brain tumor detection[14]

Deep Learning-Based MRI Analysis for Early Brain Tumor Diagnosis:

The paper employs Magnetic Resonance Imaging (MRI) for brain tumor diagnosis, emphasizing early detection. It utilizes deep learning, specifically Convolutional Neural Network (CNN), for image classification without expert reliance, emphasizing the importance of diverse data. The study compares two CNN models to classify brain tumors, achieving a prediction accuracy of up to 93% through training[8]

Fused Feature Optimization and Ensemble Classification for High-Accuracy Brain Tumor Detection:

The paper introduces an intelligent system for brain tumor detection, utilizing a fusion approach with histogram of oriented gradient and deep CNN-based neural features from MRI images. Principle Component Analysis (PCA) is employed for feature optimization, enhancing the fused feature vector. The detection is performed using a machine learning-based ensemble classifier, Bootstrap Aggregation, on optimized fusion vectors, achieving a satisfactory detection accuracy of 98.79% through fivefold cross-validation[15]

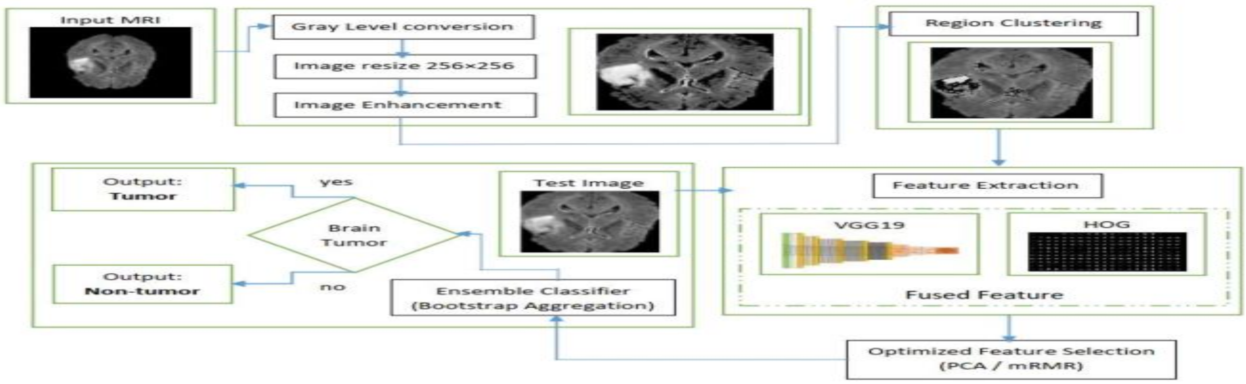

Fig.3. Flow diagram of the brain tumor detection method

Integrated MRI Processing and SVM Classification for Accurate Brain Tumor Detection:

The paper addresses brain tumor detection using MRI, employing techniques such as noise elimination, feature extraction via gray-level co-occurrence matrix (GLCM), and segmentation with Discrete Wavelet Transform (DWT). Morphological operations are applied to eliminate segmentation-induced noise, and a Support Vector Machine (SVM) classifier is utilized for accurate brain tumor detection. Experimental results demonstrate a high classification accuracy of 98.91%, showcasing the effectiveness of the proposed system[17]

BrainMRNet: Advanced CNN Architecture with Attention Modules for High-Performance Brain Tumor Detection:

The proposed BrainMRNet model utilizes a convolutional neural network architecture with attention modules and hypercolumn techniques for brain tumor detection. Attention modules are employed for image preprocessing and selection of important regions, while hypercolumn technique retains features from each layer in a structured array for efficient feature extraction. The model outperforms pre-trained convolutional neural network models (AlexNet, GoogleNet, VGG-16) with a classification success of 96.05% on magnetic resonance images[4]

Multimodal CAD Systems for Tumor Detection: A Comprehensive Survey:

The study discusses computer-aided systems (CAD) for tumor detection in various organs, including the brain, breast, skin, and lung. It emphasizes the challenges posed by image factors like poor contrast, complex background, and fuzzy borders. The survey focuses on analyzing existing methodologies and incorporates discussions on deep learning approaches in computer vision for cancer/tumor detection across different modalities such as MRI, CT, dermoscopic, mammography, and PET[13]

Enhanced Lesion Symptom Segmentation and Feature Fusion for Robust Medical Image Classification:

The proposed approach employs the GrabCut method for accurate lesion symptom segmentation and fine-tunes a Transfer Learning model, VGG-19, for feature acquisition. These features, including handcrafted (shape and texture) features, are concatenated through a serial-based method, optimized using entropy, and fed to classifiers. The model achieves high testing results on medical image databases, including BRATS 2015, 2016, and 2017, with dice similarity coefficients of 0.99, 1.00, and 0.99, respectively[12]

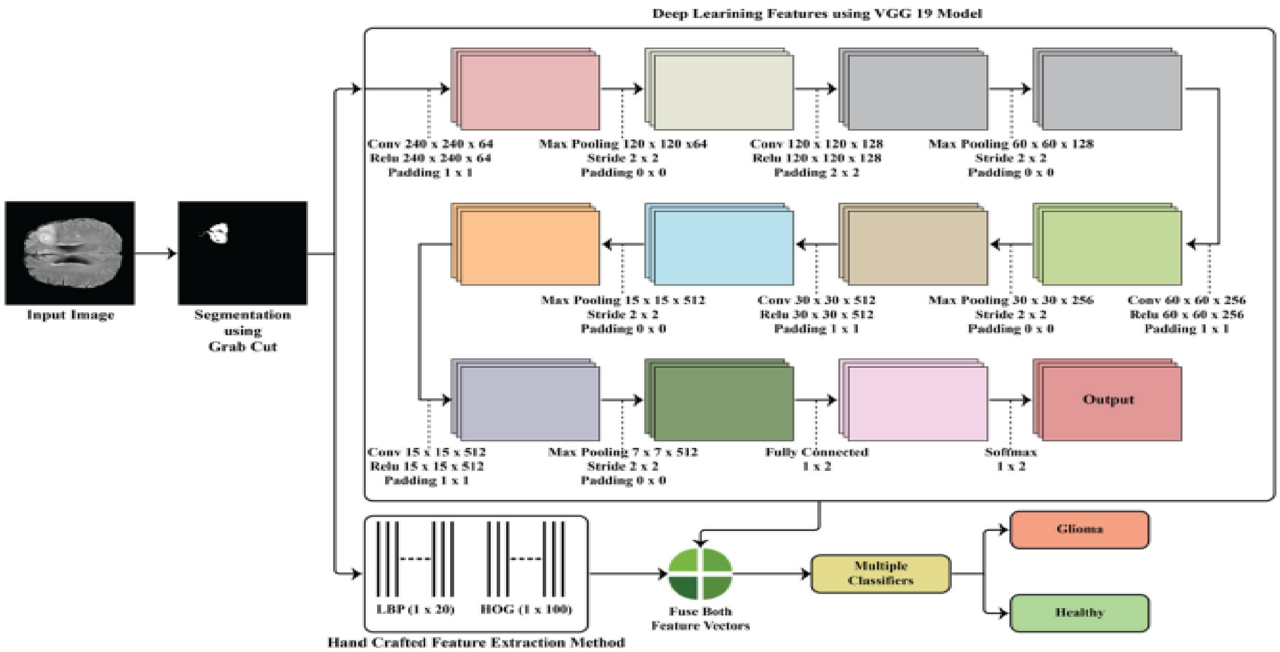

Fig.4. Handcrafted and deep features fusion for brain tumor classification

4. CONCLUSION

In conclusion, the survey of literature focused on brain tumor detection in medical image processing, particularly employing Convolutional Neural Networks (CNNs), underscores the increasing significance of deep learning in this critical domain. CNNs have demonstrated their efficacy in automating the detection process, offering a robust solution for accurate and timely identification of brain tumors. The surveyed studies highlight the continual evolution of CNN architectures, integration with advanced techniques like transfer learning and attention mechanisms, and the exploration of synthetic datasets to address challenges related to data scarcity. The collective findings underscore the promising trajectory of CNN-based approaches, affirming their pivotal role in advancing the field of medical image processing for enhanced brain tumor detection.

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