IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Brain Tumor Detection Using Image Processing

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***Abstract*—**The field of Biomedical Image Processing is expanding rapidly and is in high demand. This includes many different types of imaging methods like CT scans, X-rays and MRI. These are techniques that enable us to diagnose abnormalities in the human body. The main objective of medical imaging is to get precise information from these images with as minimal error as possible. Definitely, among several medical imaging processes MRI is the best and safest one. Magnetic Resonance Imaging (MRI) Scan uses the properties of magnetism and radio waves to come up with specific images. The most frequent used imaging method by a neurosurgeon is an MRI, because it gives them enough information to recognize all the smallest deviations.This MRI is processed and then Tumor is detected from that.

Keywords—Biomedical Image Processing, Magnetic Resonance Imaging (MRI), Brain Tumor Detection, Image Segmentation, Feature Extraction

I. Introduction

Brain tumors are effective growths of cells within the brain or central nervous system, that may be benign (non-cancerous) and is malignant(cancerous). But all the brain tumors are classified under two major categories which include Primary where it is developed to originate in Brain itself, they will not form anywhere and on other hand Secondary (Metastatic) Tumor type where that develops from certain body part and spread to another.

Research is necessary for improving diagnostic accuracy, better understanding aspects of tumor biology while also providing the foundation required to develop innovative therapeutic approaches which can effectively target tumors. The promise of imaging, genetic profiling and treatment options such as immunotherapy or precision medicine are under way but more work is needed to continue giving hope for increased survival rates and quality of life.

The key parameter in the medical recognition covers the data which is acquired from multiple biomedical devices — uses various imaging mechanisms such as X-ray, CT scan and so forth to obtain medical images. Magnetic Resonance Imaging (MRI) uses a physical principle based on magnetic field vectors created by exciting strong magnetic fields and radio frequency pulses in the nuclei of hydrogen atoms, present due to water molecules within human body used for topographic imaging [5].

MRI scan is better than CT scan for diagnosis as it does not require any radiation. The MRI for assessment of the brain can be performed by radiology. The standardized way to address tumor in MRI image is human observation.Now after we get the scan image of brain it is necessary to detect tumor and where exactly its size & area. This is all information that the Neurosurgeon needs to form his Diagnosis. This is where Image Processing comes to our rescue. This will help us in detecting the tumor accurately with various other segmentation techniques and feature extraction method.

II. LITERATURE SURVEY

Image Processing is an important as well as a complicated and hard task as detection of tumor mainly depends on it. If image is not processed thoroughly it can affect the outcome completely. To process a image we first need to remove any unwanted data or part that it may contain, so first step is pre-processing.

A.Pre-Processing:

It is a crucial step for image processing for noise reduction and image quality enhancement. It removes any unwanted data or part as it may hinder in our process later. It includes methods like Noise Reduction, Normalization, Skull striping, Contrast Enhancement.

- Noise Reduction: MRI scans often have noise which is due to equipment and scanning conditions. The benefit we get is by reducing the noise which in result sharpens our image, removing artifacts making tumor region more clear and visible. Different techniques for noise reduction are Gaussian filtering,Median Filtering, Bilateral Filtering.
- Normalization: Normalization makes sure that the intensity is consistent in whole image and there is no variance in it. It is essential as it reduces intensity variance which can affect the image processing. The techniques which are mainly used are Min-Max Scaling, Z-Score Normalization.
- Skull Stripping: It involves removing all the non-brain tissues like skull, scalp so that we can focus on brain rather wasting time on other parts. The techniques used are Thresholding and Masking, Brain Extraction Algorithms.
- Bias Field Correction: The field bias signal is a very low frequency and much smoother signal because it causes to corrupts the image generated by MRI (Magnetic Resonance Imaging) specially produced by old machines [2] Which will affect the image processing as in segmentation it not give proper results shown is figure.

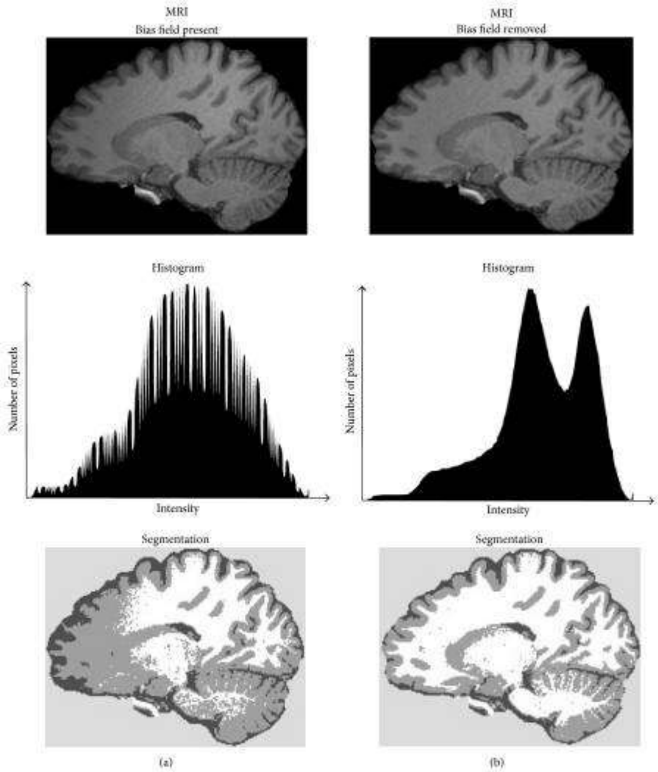

Fig. 1 Shows the influence of bias field on brain MRI [2]

B. Segmentation:

The process of splitting an image into multiple parts is known as segmentation. It creates various sets of pixels within the same image [1]. In segmentation we isolate the tumor region by delineating the tumor while measuring its size, shape and location which enable us to precisely extract and classify the tumor. Some of commonly used segmentation methods are:

- Thresholding: It is the simplest techniques as it converts the image into binary image by a threshold value then separates the object from background by selected pixel intensity threshold. Its limitation is that it fails with low contrast image where tumor intensity is low or is matching with surroundings. Mainly used thresholding techniques are global and adaptive thresholding.
- Region-Based Segmentation: In this segmentation, we group pixels based on their similar properties. The two variants of region based segmentation are top-down approach and bottom-up approach. Its limitation is that it doesn't provide accurate segmentation when there is not much difference in pixels of object (tumor) and background.
- Clustering-Based Segmentation: In this similar pixels are grouped in a cluster using clustering algorithm. One of mostly used clustering based segmentation is K-means in which k is number of group the pixels will classify in. In this we group pixels using distances like Euclidian distance[3]. Another clustering techniques is Fuzzy C-means in which unlike k-means data can belong to multiple cluster, which gives comparatively better results than k-means [7].
- Edge Detection: This segmentation is mainly divided into two steps which are edge detection and edge linking [6]. In edge detection, we analyze and detect the pixels which are boundaries or edge of the object which in our case is tumor. Then in edge linking the adjacent edges are linked to each other to segment the whole object(tumor). Its limitation is that it is unable to detect irregular sized tumor and often requires post-processing to create or identify the object. Some of commonly used techniques are Sobel, Canny, and Prewitt Filters.
- Atlas-Based Segmentation: This method uses an atlas which is an standard reference of brain structure and uses it for segmenting the new images. The performance of this technique is mainly based on the atlas or reference provided to it. It aligns the atlas to image and then segments it accordingly. However its limitation is that the brain develops according to age as a newborn baby brain is much different than an adult's , so the atlas provided must be according to the image to be segmented otherwise it will affect the output or result.
- Deep Learning-Based Segmentation: Deep learning segmentations like Convolutional Neural Networks (CNNs) are much more accurate and can do real time segmentation which are great help in surgeries which increases the surgery accuracy and minimizes the damage to other tissues. It requires a large labeled data to train and if the dataset is small or lacking the result may not be useful.

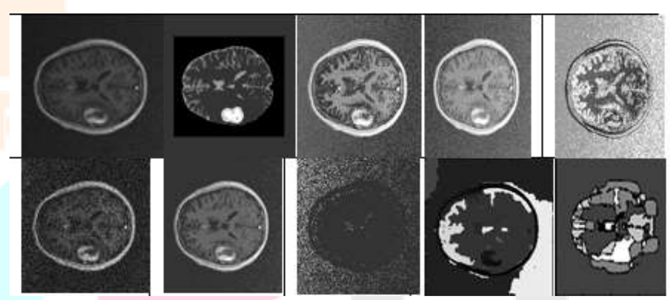

Fig. 2 Results from various different segmentations (a) original image, (b) ground truth image, (c) FCM, (d) K-Means, (e) SCFCM, (f) MS, (g) EM, (h) MRF,(i) PCNN (j) SVM. [4]

C. Feature Extraction:

In feature extraction we derive all the information or data from the segmented tumor from the image which helps us in classification and diagnosis. Feature extraction is used for tumor type detectionand monitoring change process. Few of feature extraction types are:

- Intensity-Based Features: It captures the distribution of pixel intensity of tumor.Such characteristics can help to differentiate between malignant and benign tumors, since the intensity profiles differ for malignant and nonmalignant masses. Some common intensity based are Mean Intensity,standard Deviation of Intensity.

- Texture-Based Features: It captures the pattern of the tumor in brain and can help in differentiating type of tumor or whether it is malignant or not. Some of common texture based features are Gray Level Co-Occurrence Matrix (GLCM), Gray Level Run Length Matrix (GLRLM).
- Statistical Features: These are the characteristics which are derived from data through which we can find its properties and pattern of tumor. Some common statistical features are mean, median, variance and kurtosis.
- Hybrid and Custom Feature Extraction Techniques: Hybrid techniques combines multiple feature types to get more data on tumor type or how much of brain tissues have been affected by it.

D.Classification:

Classification from the detected feature or image data is nothing but detecting and categorizing a tumor. The classification process is used to determine if a tumor is benign or malignant, and also can subtype tumors. This can be anything from standard machine learning models to advanced deep learning models each providing an appropriate set of advantages depending on your data availability, computational resources &accuracy. Some of commonly used classification techniques are:

- Traditional Machine Learning Approaches: Traditional machine learning approaches are effective in brain tumor classification, especially when the labeled data is limited. These approaches work effectively when they are combined with good features (intensity, shape, textures). Some of commonly used machine learning algorithms are:

1. Random Forest: It is a methods in which multiple decision trees are build based on subsets of data and then combines all of them for final result. It can identify important features such as textures and shape making it useful for interpretation.

2. Logistic Regression: It is a linear model that estimates probability that the object belongs to a certain class or not [8]. It is mainly used to differentiate between benign and malignant tumorsusing the extracted features such as intensity , shape and textures.
3. Naive Bayes: It is a probabilistic classifier which is based on Bayes' theorem and is mainly used where features are statistically independent. Its limitation is that it assumes that the features are independent which is rare in real world medical, so it is unable to work on complex patterns.

Traditional machine learning methods are effective and efficient on smaller dataset but are outperformed by deep learning on large dataset.

- Deep Learning-Based Classification: Deep learning refers to a subset of machine learning model that are based on artificial neural networks with multiple layers trained by iterative processes between input data and output labels [9].Deep learning models such as CNN has proven highly effective in image classification as they can learn quickly and effectively from the data provided and use it in image classification effectively.

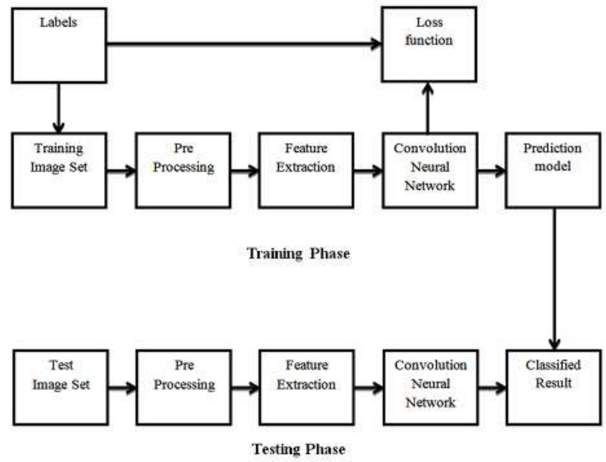

Fig.3 Block diagram of proposed brain tumor classification using CNN[10]

- Hybrid and Ensemble Methods: By combining both machine learning and deep learning methods, hybrid model aim to improve the image classification accuracy by using strengths of both models. Some example of hybrid are Hybrid of CNN and SVM, Stacking Ensemble model

III. CHALLENGES

A. Data Limitations

The scarcity of large-scale, annotated image datasets is one major obstacle in the proliferation of computerized detection and segmentation methods for brain tumors. Such datasets, for example the Brain Tumor Segmentation Challenge (BraTS) dataset provide a standardized collection of labeled brain tumor images but not as diverse and large to span all types of tumors, patient demographics & imaging modalities one may encounter in real-world clinical scenarios. The lack of diverse annotated data makes machine learning models susceptible to low generalizability because real-world imaging machines and parameters can contribute significantly to the variation between training set properties (Menze et al., 2015).

B. Tumor Heterogeneity

They could be of any size, shape or texture and in a different location which impairs the fast detection and classification accuracy. Due to this heterogeneity, it is hard for traditional machine learning methods to generalize well across those different variations. More advanced methods like deep learning based approaches with generative models or attention mechanisms are also studied to further increase the sensitivity of capturing tumor characteristics. However, there are limitations to these approaches due to the complexity and variability of tumors.

C. Computational Complexity

Processing high-resolution medical images poses significant computational requirements, especially from deep learning-based models that are memory and compute-intensive during both training and inference stages. This requirement can pose an obstacle for smaller medical facilities that do not possess high-performance computing infrastructure. Hence, solutions like cloud-based computing or other model optimization techniques such as pruning and quantization can help to fix this problem but at the expanse of monetary costs (Ismael et al. 2020).

D. Precision of Segmentation and Border Determination

Accurate tumor region segmentation is one of the challenges in brain tumor diagnosis, especially at the location where benign and normal tissues are adjacent. Misclassification of the boundary can result in incomplete detection, where parts of the tumour (will) be missed and inclusion/exclusion misalignment with regards to non-tumorous regions. Especially in the presence of ill-defined borders and low-grade tumors that makes this even more difficult. Fine-grained segmentation improvements with CNNs and U-Net architectures have been very helpful but the localization accuracy of boundaries remain a significant challenge.

E. Artifacts and Noise in Medical Imaging

It is common for MRI images to contain noise or artifacts due to patient motion, machine error and environmental factors. These disturbances make it difficult to accurately identify and segment tumours. Filtering and noise reduction algorithms are typically introduced to enhance the quality of images through preprocessing techniques. They are capable of changing certain image aspects that are important in the detectability of minor tumor characteristics, and therefore the detection performance can be affected.

F. Labelling and Annotation Issues

Building labeled datasets needed for training machine-learning models has been a labor-intensive process that relied on expert radiologists to label images. Annotation fallacy across experts again is another cause of difference in the dataset, which then makes harder to train any kind of model. Methods like semi-supervised learning and transfer are examined in order to exploit partially or weakly labeled datasets, but the quality of these annotations still poses a particular challenge.

G.Interpretability and Explainability

Interpretability is an increasingly urgent concern as brain tumor detection models become more intricate using machine learning. Knowing why a model arrives at any one decision is crucial in medical domains and especially for life-threatening diagnoses such as brain tumors. Most deep learning models, such as CNNs, are inherently "black-box" systems, which further complicate the interpretability of their outputs for clinicians. Work is being done to bring explainability through saliency maps and attention mechanisms but they are in their evolution process.

H. Privacy and Security Concerns

As these needs continue to grow there is potential in moving towards cloud-based computing, but should this occur questions will arise regarding patient data privacy and security. The cloud-based storage and processing of medical images may expose such data to breaches or unauthorized access. Moreover, tools used for brain tumor detection must maintain compliance with data protection regulations like HIPAA and GDPR that needs strong encryption along with moving to anonymize increments of the gathered information which thereby increases the inclusive costs & burden associated in such solutions.

IV. CONCLUSION

Our literature review shows that image processing can play a big role in detecting brain tumours by segmentation and classification tasks managed with machine learning (ML) or deep-learning DL techniques. These methods appear promising for improving diagnostic accuracy and offering assistance in determining a spectrum of pathological characteristics more precisely. Nonetheless, a lot of restrictions remain in the field, especially in terms of availability related to data. Robust models require a large, diverse training data set which is however lacking as it takes time to collect and label the high-quality medical data. Challenges also arise in attempts to widen the range of datasets, mainly because obtaining funding is challenging and existing public datasets may not represent a broad array of tumor heterogeneity coupled with differing imaging protocols found across various healthcare domains.Also, over the years various software libraries have been supporting research in programming languages and middleware development through incremental progress which has resulted in researchers having to deal with compatibility issues across tools ecosystems posing hurdles for direct execution of advanced ML/DL algorithms.

Despite the daunting task, there is hope of advancements in detection methods for brain cancers through research and collaborative effort between disciplines. Dealing with these concerns is going to take effort from Computer Scientists, Healthcare Professionals and Policy Makers alike: ensuring the delivery of effective funds adjusted for specific articulations that turn over for data sharing & privacy compliance. In addition, advances in programming languages and middleware as well as computational infrastructure are expected to address some of the current performance bottlenecks while also increasing usability and reliability of computer vision applications clinically. This type of gap bridging may result in tools which are not only technically sound, but also user-friendly and suitable for broad clinical deployment — a development that could truly revolutionize our approach to brain tumor diagnostics as well as patient care.

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