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A Comparative Study on Brain Tumor Detection Methods using MRI Scans

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Abstract: *A brain tumour is formed due to the overgrowth of abnormal cells inside the brain. There are several types of tumours that are broadly classified based on their cancerous properties as malignant tumours or cancerous tumours and benign tumours or non-cancerous tumours. They can either begin in the brain and be known as primary tumours or spread to the brain from another body part and be called metastatic. These tumour developments can be life-threatening if not detected and treated at an early stage. MRI or Magnetic Resonance Imaging Scans serve as the preliminary test to diagnose a tumour. Then, further analysis is done by the neurosurgeons for prescribed medical care and treatment in the future. About 40-50 thousand patients suffer from a brain tumour growth every year in India. Thus, it is crucial to enhance the efficiency of the health sector by automating tasks that require preliminary diagnosis to reduce the burden on doctors and provide critical patients with timely care and treatment. Hence, this project proposes to develop an algorithm to detect brain tumours from MRI Scans on MATLAB and also provides a comparison between the different models that can be implemented to perform this task. The proposed algorithms in this study reflect the importance of creating a system that directly detects tumours without the requirement of complex machine learning algorithms that require the use of training and testing data sets.*

Keywords: Tumour, MRI Scans, MATLAB, machine learning algorithms

I. INTRODUCTION

1.1 Background Study

The unregulated and abnormal accumulation of cells within the brain leads to the formation of tumours. These can be primary tumours (that stay contained to one part of the brain) or secondary/metastatic (that spread from different locations of the body to the brain). The noncancerous tumours are called benign and malignant tumours are cancerous. There are several types of brain tumours as well. To name a few, Glioma, Meningioma, Pituitary, Glioblastoma are commonly seen. Patients require exceptional care and treatment from the medical sectors and their general treatment options include surgery, radiation therapy, chemotherapy, targeted therapy, and clinical trials. An MRI Scan (Magnetic Resonance Imaging Scan) is the first step towards identifying a brain tumour. Highly detailed images of the cross-sections of the brain can be produced due to the strong magnetic field and high frequency radio waves. MRI is usually safer than X-Rays and cause less damage to the body tissues. They can be used to diagnose or investigate any abnormalities on soft tissues like tumours, damaged ligaments, injury or diseases on joints and internal organs.

1.2 Motivation and Objectives

To reduce the burden on the doctors and nurses to verify the results of each MRI Scan generated in their workplace, this project aims to automate the task of identifying any abnormalities within the brain and hence, look for tumours from the scan results. This not only prevents the doctors from manually checking each scan for each patient but would also help the healthcare workers to efficiently treat critical patients and create a hitch-free system for timely diagnosis. Leading with this background study and motive, we have proposed a system that would:

1. Detect Brain Tumours from MRI Scans
2. Improve the accuracy of detection by verifying results across different algorithms

Segmentation of tumours from medical images is considered one of the major challenges in the medical industry due to the overlapping of tissues. The accurate knowledge of these segmented regions plays an important role in the diagnosis and treatment of benign as well as malignant tumours. Using a variety of algorithms to locate the boundaries of the tumour

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in the brain, this project can help doctors to plan and operate patients to give timely care to critical patients. This study can also be implemented to a variety of future diagnostic prospects and provides tremendous scope for research.

1.3 Features

The proposed brain tumour detection project uses four different algorithms –

A. Splitting the different regions of the brain by extracting the skull and then highlighting the tumour

- Convert the imported image to grayscale.
- Adaptive Thresholding done to threshold local regions of the image to improve the segmentation results.
- Extract different regions of the brain.
- Remove the region with the largest area (here we presume that the skull has the largest area).
- Highlight the next largest cluster – tumour.

B. Colour Mapping to detect intensely coloured regions of the brain signifying the tumour

- Use jet and turbo mapping to indicate highly intense regions of the brain image after grey scaling.
- Convert the monochrome or colour mapped image to colour and extract out different primary colour bands.
- Assign a threshold value to red colour – displaying highly intense pixels – signifying tumour and threshold the green and blue colours to 0.
- Filter out the objects with extremely small/negligible areas.
- Detect red blobs – tumour regions.

C. K-Means Clustering

- Using Gabor filters, filter and smoothen the images to improve segmentation.
- Perform K-Means clustering to attain 3 clusters where the inner most cluster will give us the tumour region.
- Display objects in each cluster and create a mask to show the nuclei or the tumour in white.
- Mask out all the other regions with black.

D. Filtering and Canny-Edge Detection

- Filter the uploaded MRI Scan after binarizing the grey scaled image using:
  Entropy (ii) Weiner (iii) Gradient Magnitude Filters.
- Extract and remove the largest part of the brain from these filtered images – skull – using Method-1.
- Highlight the tumour region using Canny-Edge Detection.

II. PROPOSED SYSTEM

2.1 Data Set Description

For the purpose of this project, the image data has been collected from Kaggle. MRI Images from three different classes have been selected namely, Glioma, Meningioma and Pituitary Tumour. A collection of 90 images were tested with each of the developed algorithms and the tumours were highlighted. The actual data set consists of about 3000 images and thus, the efficiency of the proposed algorithms can be tested with the entire data set as well. The first and foremost advantage of this proposed algorithm is of not requiring a training and testing data set over any other Machine Learning model. Segmentation and Feature Extraction can be performed on the uploaded images to look for abnormalities.

Our image data proved to be efficient to give a preliminary analysis on the functioning of each of the proposed algorithms. The axial plane of the image has been extensively utilized for the detection of the tumour as this gives a clearer depiction of the tumours and helps identify even small abnormalities clearly.

2.2 Methodology

The proposed methodology, as depicted in Fig.1., for each of the four algorithms have been elaborated upon below. The MRI Scans from the image data-set collected are first imported into the working environment of MATLAB R2022a software. The images are in their black-and-white format and need to be converted to grey-scale in order to ensure that

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further processing can be done on the same. [7] Thus, the user selects the image to be used for analysis from their device and it is then converted into grey-scale. The image is also resized in order to create uniformity among the analysed image with its raw form for a comparative study. Next, thresholding is performed on the grey-scaled image.

Thresholding segments images by setting the pixels with higher intensity values to a foreground value and others to a background value, in order to contrast pixels for further analysis. Adaptive thresholding changes the image threshold dynamically, enabling a sophisticated gradient of the image. This technique creates a binary image representing the segments according to pixel intensity. Local Adaptive Thresholding is hence implemented on the grey-scale image to attain a binary image for segmentation and analysis.

Following these implementations, the image is now ready to be applied to each of the four algorithms.

Splitting the Brain Image Region-Wise to Highlight the Tumour (Algorithm-1):

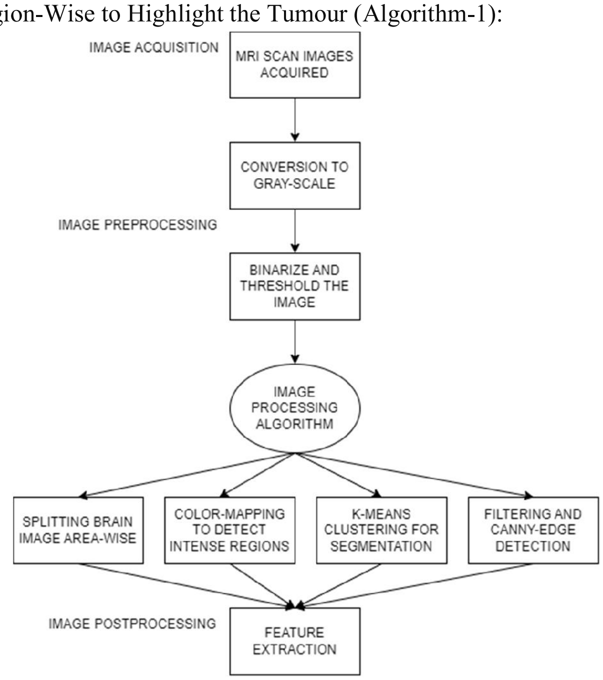

Figure 1: Block Diagram of proposed methodology

masked out. Then, from the remaining sections, the component with the largest area is again highlighted and is presumed to be the tumour. The boundaries of this tumour region are then outlined.

Colour Mapping to Detect Regions of High Intensity (Algorithm-2):

The second approach uses colour mapping to detect regions of the binary image that have highly intense colour denoting high pixel density and thus indicating the tumour region. Jet Colour Mapping is applied to the image to attain a contrast between the image parts according to the pixel density. The areas of high pixel density are highlighted in red and further analysis is done to ensure that this region is indeed the tumour. The jet colour mapped image is then colour coded to get a "rgb" image which will then have a high contrast between the highly dense regions with the background. This will help in detecting the tumour. Each of the Red, Green and Blue bands are extracted out and the blue and green are masked to 0. This will in turn, only highlight the red – highly intense pixel regions and denote the tumour. Regions with very small area are removed from the analysis since the identification of a tumour requires the red blobs to be of a significant size.

K-Means Clustering for Image Segmentation (Algorithm-3):

This popular unsupervised learning algorithm groups unlabelled data into clusters based on similarities. Image segmentation can be performed using K-Means Algorithm to separate pixels in a two-dimensional space and find k clusters. [7] We have segmented the MRI Image into three clusters: the background, skull and tumour. The algorithm iterates to calculate the closest distance among pixels and hence group them into one cluster. The centroids are thus recentered as well with every iteration. The image is initially converted to a different colour space and then is used for

K-Means Clustering. Here, the tumour region is highlighted by cluster-3 and the rest is masked out. The pixels with higher intensity are grouped together in the final segmented image as the tumour.

Filtering and Canny-Edge Detection (Algorithm-4):

The last algorithm proposed makes use of various filters to enhance the image for detection. Filtering allows specific features in the image to be emphasized and thus would increase the probability of correct predictions or detections. [1] This implementation is split into four sub-methods whereby a different filter is used to filter the original image and it is then split into regions to extract the skull and remove it, followed by Canny Edge Detection applied on the filtered image to identify the tumour. Each of these filtering techniques has their own benefits and detects a specific type of tumour scans. A brief summarization regarding the filters used and their advantages is given below.

A. Entropy Filtering (Algorithm-4a): Entropy Filters are used to return the randomness of a pixel and are ideal to measure the textures within an image. This form of statistics can provide information about the variation in the intensity of pixels. Areas with smooth texture have a small entropy value and rough texture have larger entropy values.
B. Wiener Filtering (Algorithm-4b): This filter is considered an optimal filter for signal processing as it best approximates the desired signal by minimalizing the mean square norm of the error (MSE). It can function very well even in the case of blurred images and since inverse filtering fails in certain circumstances, it provides as a great substitute.
C. Laplacian Filtering (Algorithm-4c): Laplacian filters calculate the second derivatives of the image to measure the rate at which the first derivative changes. It is commonly used as an edge detector in digital image processing and proves to be highly advantageous due to its ability to reduce spatial noise and enhance prediction accuracy.
D. Median Filtering (Algorithm-4d): This technique is used for noise reduction and removal from images. It preserves the sharp edges and contours of the image while filtering and hence is an important tool for image processing.

Canny Edge Detection is then applied on each of these filtered images. [5] It is a technique popularly used to extract useful information about the structure of the images and reduces the quantity of data required to be processed. It produces very thin and clean edges by minimizing the distance between the detected and original edges. It also gives only one response per edge, improving its efficiency. Applying canny edge detection after filtering the MRI Scans ensures that the detected tumour is accurately highlighted.

Each of the algorithms have also used the tic-toc function to calculate the time elapsed for the code implementation. This will help compare the efficiency of the proposed methods. [6] A prompt has also been implemented within the code application to enable users to suspend their program if the required tumour has been detected even before the code completion. This would greatly reduce functionality time and also create an interactive system for specific application-oriented purposes. The area of the identified tumour has also been displayed.

III. SYSTEM IMPLEMENTATION AND ANALYSIS

The four proposed algorithms have been implemented and the outputs of the detected tumour have also been illustrated. Each of the four proposed algorithms have a different functionality and allow for an ensemble mode of tumour detection and verification.

The code has been written on the licensed MATLAB R2022a version and functions have been implemented using the Image Processing Toolbox.

3.1 Results and Discussions

Each of the depicted outputs obtained highlight the diversity of the various algorithms and also the versatility of their applications to the various types of tumours, namely Glioma, Meningioma and Pituitary.

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Splitting the Brain Image Region-Wise to Highlight the Tumour:

The implementation of this algorithm is illustrated in Fig. 2. Glioma and Meningioma tumours are usually visible through the axial scan and hence can be easily detected through this code implementation. Pituitary tumours are more difficult for identification and yield low accuracy.

Colour Mapping to Detect Regions of High Intensity

Colour Mapping results are depicted in Fig. 3. This algorithm can detect very small tumours as well, contributing to its higher accuracy and scope for industrial applications. The colour mapping technique highlights regions of high intensity, and, converting the jet colour mapped images to *rgb* creates a prominent diversification among the three primary colour bands. Thus, extracting the *red* or highly dense pixels from this image would give accurate depiction of tumorous masses within the brain.

K-Means Clustering for Image Segmentation

K-Means Clustering Algorithm is a Machine Learning Algorithm that clusters data according to their proximity from its center depending upon their similarities. Three clusters are being created in the implemented methods visible through Fig. 4. The inner most cluster is considered to be the tumor with cluster center-3. The nuclei identified pixels depict the pixels with highest intensity clusters with a threshold value of 191, as found by trial-and-error. These pixels are then set to 255 to highlight as tumor in white.

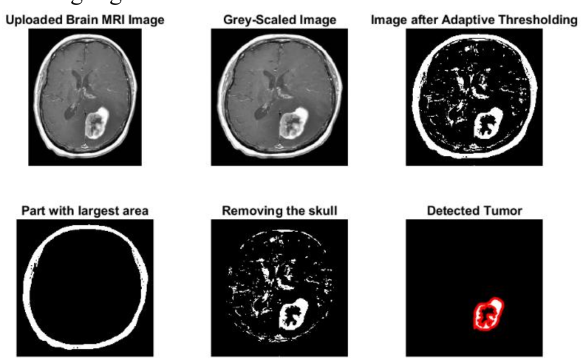

Fig. 2 Glioma Tumor Detection using Algorithm-1

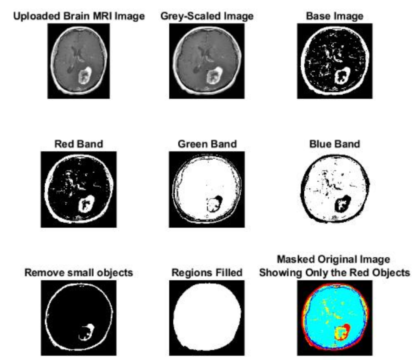

Fig. 3 Glioma Tumor Detection using Algorithm-2

Filtering and Canny Edge Detection:

Each of the mentioned filtering techniques have been implemented and illustrated through Fig. 5a, 5b, 5c and 5d respectively. Canny-Edge Detection helps remove the noise in the data using Gaussian Filtering. Hysteresis Thresholding method is then used to preserve the pixels at higher intensity values and neglect the ones below the threshold. It thus provides with efficient detection of edges and localization

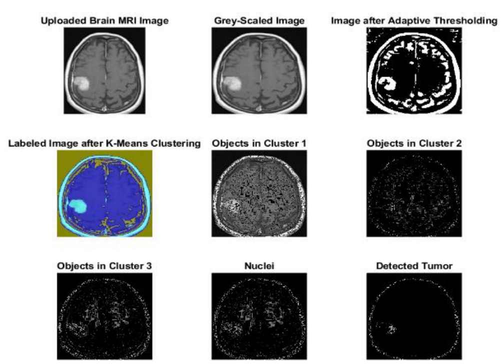

Fig. 4 Meningioma Tumor Detection using Algorithm-3

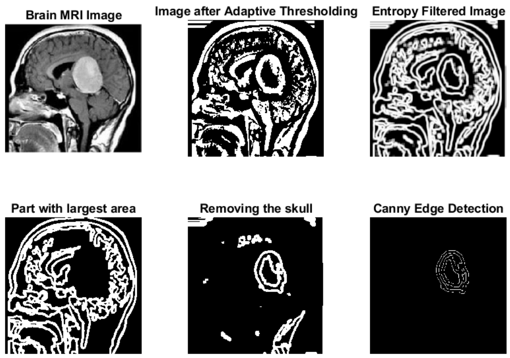

Fig. 5a Meningioma Tumor Detection using Algorithm-4a

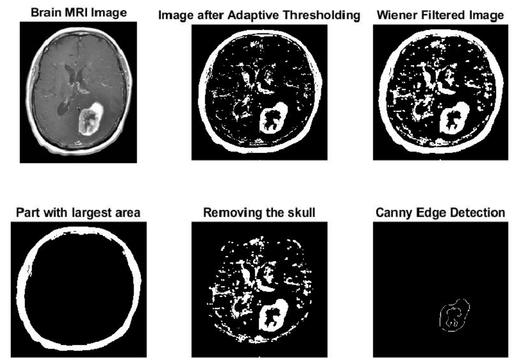

Fig. 5b Glioma Tumor Detection using Algorithm-4b

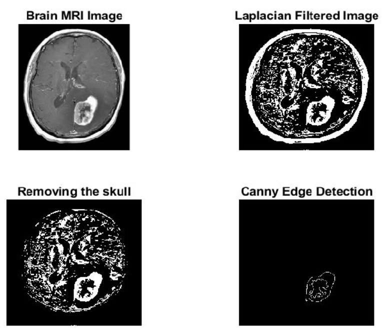

Fig. 5c Glioma Tumor Detection using Algorithm-4c

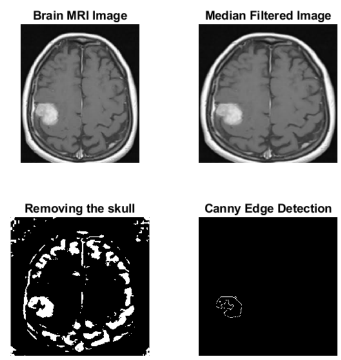

Fig. 5d Meningioma Tumor Detection using Algorithm-4d

3.2 Inferences

The implemented algorithms for the custom data set of 90 images – 30 glioma scans, 30 meningioma scans and 30 pituitary scans emphasize that the methods consisting of Jet Color Mapping and K-Means Segmentation are highly accurate and also computationally efficient. The Table-I summarizes the minimum and maximum time duration elapsed for each of the implemented algorithms. Thus, the average time and accuracy for all the tested cases have been specified. Out of the 90 tested images, 40 images gave accurate tumor detection results with the first algorithm implementation. 81 images gave the correct detection using the second, 83 images using the third and 66 images using the fourth algorithm. Thus, the accuracy is highest for the second and third methods and they also give the lowest time elapsed on an average. These algorithms can create an efficient detection prototype within hospitals to ensure automated detection and even classification of scans.

TABLE I

Algorithm Implemented	*Minimum Time Elapsed (seconds)*	*Maximum Time Elapsed (seconds)*	*Average Time Elapsed (seconds)*	*Accuracy (percentage)*
Algorithm-1	3.38	22.09	8.849	44.44
Algorithm-2	2.92	11.01	5.087	90
Algorithm-3	8.83	12.34	10.13	92.22
Algorithm-4	2.96	26.32	7.31	73.33

3.3 Comparison with Existing Algorithms

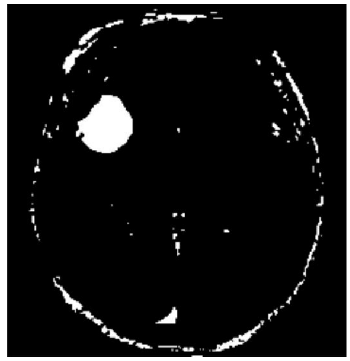

Fig. 7 Existing Segmentation Algorithms

The tumour segmentation and detection through image processing techniques have evolved over the years. The existing algorithms conventionally filter the image through either a gaussian filter or median filter and then perform segmentation using Watershed segmentation or K-Means. [21] Fig. 7 demonstrates the usual methodologies used for analysis and highlights only the larger and aggregated sections of the tumour. Thus, the proposed system ensures that analysis of even scattered tumour particles are detected using colour-mapping and edge detection. Primitive analysis of large number of scans can be automated using such algorithms. [12] Deep Learning algorithms also create efficient systems for tumour detection and classification. Integrating these CNN models with image segmentation techniques described in this paper can improve the accuracy and also provide sufficient proof of concept for clinical trials.

IV. CONCLUSION

This research paper illustrates a comparative study on the four different detection techniques of brain tumours from the MRI Scan Images. MATLAB is a powerful tool for Image Processing and enables the use of several functions and features that allow us to manipulate particular regions of the image. The four proposed algorithms each have their own benefits and this work can be integrated with further analysis to classify the detected tumours as well. Although these algorithms do not have a hundred percent accuracy, it is still evident that some techniques like the use of Colour Mapping and K-Means Segmentation give substantial results and can be implemented to the industrial applications.

Preliminary testing to identify tumours and also classify them are of immense importance due to the abundance of patient data created at hospitals each day. The health-care workforce could greatly benefit by automating such tasks and also divert immediate care to critical patients at hospitals. This study is only a beginning to a potentially fruitful avenue and can be extended to detection and classification of other diseases through scans like Tuberculosis, Ovary Cysts, Stomach Ulcers and many more.

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BIOGRAPHY

Mansi Dhanania is a third-year undergraduate student pursuing Electronics and Communication Engineering from Vellore Institute of Technology. She is passionate about the application of signal processing and machine learning algorithms in the health-care industry to improve treatment efficiency.