INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 7, Issue 2 - V7I2-1496)
Available online at: https://www.ijariit.com

Brain tumor detection and classification using convolutional neural network

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ABSTRACT

Brain tumors can cause cancer if not detected and diagnosed at early stages. Currently Brain tumor detection and classification is done by performing Biopsy which is a very time consuming process. Improvement in technology and Machine learning algorithms can help radiologists in tumor diagnostics in less time and effort. We propose a model that would first segment the MR image and identify the presence of tumor in brain and if detected then a deep learning based CNN architecture that would classify the tumors in MRI images into Benign and Malignant tumors and act as a strong base for the staff to decide the curing procedure. The development of the model will be divided into training and testing phases and would be tested using multiple databases and different methods. Having achieved high accuracy, reliability and execution speed, the developed CNN architecture would act as strong decision supportive tool in medical diagnostics for radiologists.

Keywords: *CNN, Brain Tumor, Fuzzy C-Means, Gaussian Filtering, Benign, Malignant, Skull Stripping, Brats, Neural Network*

1. INTRODUCTION

1.1 Overview

Accurate brain MRI images are very important for the clinical diagnosis of tumor in brain. Since the tumors have almost similar structures, it is very difficult to identify the exact portion and type of tumor even for experienced doctors. It also depends on availability of radiologist. Automaticdetection and classification of tumor without much human interference would be a very useful solution to this difficult problem.

In order to build such a well trained and reliable model, Deep learning algorithms particularly Convolutional Neural Networks have been very successful. CNN can examine the images, identify useful information and extract patterns that can be used for classification.

MRI images are very clear, precise and provide information about size, shape and the position of tissues with very less ion radiation. Hence MRI images instead of CT images have been used in training this model. MRI images do contain many unnecessary information hence before feeding as input to the CNN model, we need to extract only the useful portion from the image. For this task we are using Skull stripping, clustering and segmentation using FCM and tumor contouring. The output image will be directly fed as input to the CNN module.

Accuracy and reliability are very important features especially in a medical domain project. Hence we are using a multilayer CNN model and also large datasets from kaggle,BraTS'2020 data and other websites to train and test the model in order to increase its accuracy and reliability.

1.2 Motivation

We have always wanted to work on a project that would actually be useful and can help us contribute to the society. There is a lot of scope in medical and healthcare domain and since we wanted to contribute and bring a change, what could have been better than working on a project in medical field that would revolutionize the way things have been. We researched and found out about this issue of manual brain tumor detection.

Brain tumor is very critical disease and can definitely prove fatal if not identified and diagnosed at early stages. There are more than 1 millions cases of Brain tumor in India every year. Detection of brain tumor is a very difficult process hence a trained model for its detection and verification by doctors would be very useful to the medical sector.

2. LITERATURE SURVEY

2.1 Existing Methodologies

2.1.1 Brain Biopsy Method: Brain tumor detection and classification is a very difficult process to be done manually even for experienced and trained doctors due to similarity in structures of the tumors. By looking at the brain MRI or CT scan, It is possible for the experts to identify whether tumor is present or not and the region of the tumor. But it is difficult to identify the small dissimilarities in the structure of tumor and classify it into types. Hence this manual process gets stuck here for verification of type of tumor.

Type of tumor and its exact position and other details are found out by doctors by performing a medical process called Biopsy. Brain Biopsy is a process in which a portion of the abnormal tissue of your brain is extracted by first giving you anesthesia and then using a medical needle methodology to extract the part from your brain. This isa very delicate process and not all doctors can do it. Only expert Neurosurgeons can perform Biopsy.

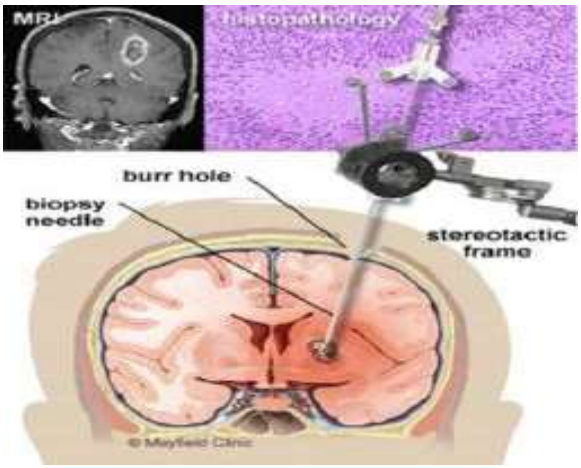


Fig.1 Brain Biopsy Method

After the sample is extracted, It is examined under microscope and various tests are performed on it to obtain the type of cell. Only then the doctor can suggest you furthertreatment plan. Result can be obtained in 5-7 days .Brain Biopsy is difficult from Biopsy of other body parts as it is a very delicate region. Hence Brain Biopsy cost can vary from Rs.7000 to Rs.12000 in India. Also it is a time consuming process and usually an entire procedure may take about 15 days. Performing Biopsy is definitely important if thetumor is identified to be Malignant. But if using this model, if tumor is found out to be Benign type than Biopsy can be avoided. Instead simple tests like Angiogram can be done to verify and then suggest further treatment plan for the patient.

2.1.2 Machine learning based Method: Brain tumor can also be detected and classified using Artificial intelligence, Machine learning and Deep learning approaches. Algorithms such as Support Vector Machine and Logistic regression have been proved useful in this field although these models are just proposed but not actually in use due to accuracy and reliability issues. Hence a more accurate and reliable method using CNN can be useful for detection and classification of brain tumor.

2.2 Proposed Methodologies

We propose a model trained using Deep learning algorithm Convolutional Neural Network that would identify the presence of tumor in brain and also the type of tumor in brain with high accuracyand would have the capability to replace the existing system in future.

Many such models have been proposed before but they were just able to identify the presence of tumor and not its type and also their accuracy was less due to less dataset and different methodused. Also they did not have any facility of medical assistance or consultation from doctor which we have tried including in our project to serve users with maximum facilities. Hence no such model is currently being used.

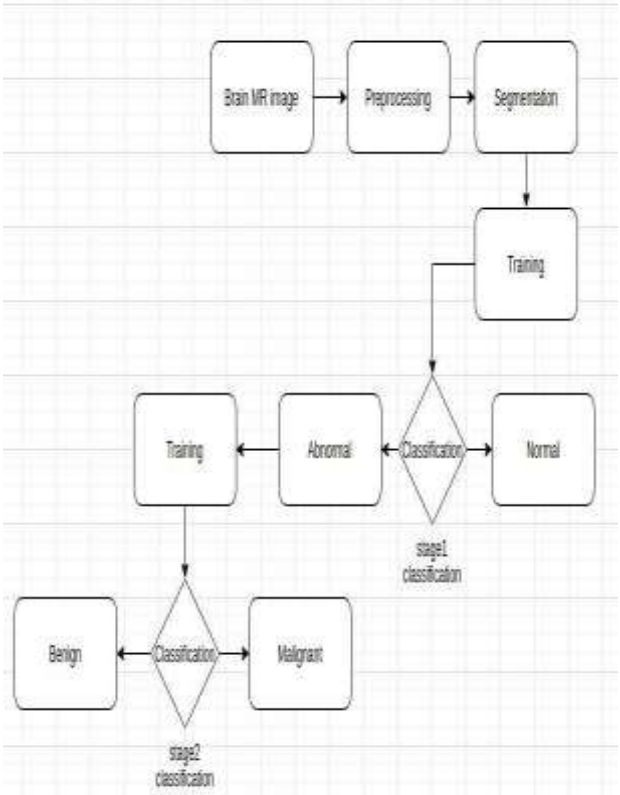


Fig1.Work Flow diagram for the proposed methodology

The entire project will be mainly divided into three modules i,e..the Image Pre-Processing module the Detection module and the Classification module. The output of the detection module will befed as input to the classification module. The entire preprocessing of image, Skull stripping, Gaussian filtering and segmentation using Fuzzy C-Means clustering will be done in the detection module .If the tumor is detected, then tumor image will be fed as input to the classification module which will have a multilayered CNN architecture.

We have tried to increase the accuracy by using a large dataset for training as well as testing. The dataset used is from Kaggle,BraTS'2020 data and image net. Also our proposed multi layered CNN model will filter the image and extract necessary information and the final output will be a combined classified result of all the layers.

This proposed system is specially designed for doctors so that can verify their result with the result generated from this system and suggest further plan to the person. If the result comes out to Benign than the patient can be just kept under observation and regular tests from time to time

This system can also be helpful to patients who have symptoms of brain tumor and MRI facility in their town but no availability of expert doctors. In such a scenario, a patient can check the result from this system and if needed can consult a doctor.

3. REQUIREMENT SPECIFICATION AND ANALYSIS

3.1 Problem Definition

To develop a web application using artificial intelligence deep neural networks that would study brain MRI images and detect the presence of tumor in brain also classifying the tumor into Benign or Malignant category and provide the highlighted tumor part with details of shape and size as output.

3.2 Concept

1. There are two types of brain tumors i,e.. Benign and Malignant tumors. Benign tumors are non cancer causing tumors whereas Malignant tumors have the ability to cause cancer if not diagnosed at early stage.
2. Patient with Benign tumor might not need to do any surgery and can be kept under regular supervision and checkup. Malignant tumor patients have to go through complete diagnosis procedure and chemotherapy sessions regularly so that theydo not become cancerous.
3. The symptoms of brain tumor are severe headache, nausea and vomiting, drowsiness, fatigue, memory and sleep problems. If a patient has these symptoms then he/she must get his diagnosis done. To make things quick and easy without much human interference. All you need to do is upload the brain MRI in desirable image format and system will do everything and generate the result.
4. The type of tumor is an important factor for doctor in deciding the diagnosis plan. Currently Biopsy is performed to detect the type of brain tumor which is a very costly and time consuming process.

We aim to train a model using deep learning Convolutional Neural Networks that would study brain MR image ,identify the presence of tumor and also its type very quickly and easily without much human
interference.

3.3 Scope

Classification using brain MRI Images only. CT scan images cannot be usedto get the result.MRI images must be of the format jpg/jpeg/png. Any other image format is notacceptable. .User location details necessary to get details of nearby clinics and hospitals where consultation and diagnosis available.

3.4 Objective

1 To gather large amount of original brain tumor MR image dataset in desirable Image format for training the model so that we have to perform less dataset augmentation and accuracy of the model will increase.
2 To train and test the detection model using large dataset as its output will be directly fed to the classification model to get the final output.
3 To design and use multiple layers and filters in the CNN classification model so that specifications and features can be extracted such that the model accuracy in classification increases and it becomes more reliable.

3.5 Project Requirements

3.5.1 Datasets: We will utilize BraTS 2020 dataset The picture information comprises 369 multi-contrast MR checks from glioma patients, out of which are low-grade (lgg) and some are high-grade(hgg) glioma patients. The pictures in datasets are formed by following kind of MRI strategies:T1, T2, FLAIR. The dataset we are going to use is from BraTS 2020, kaggle.

3.5.2 Functional Requirements: Functional Requirements include all the product's actual features, and the ones userinteracts with. All the product features, functional requirements are mentioned below:

- **Load Patients Dataset** : System deals with existing arrhythmia data and performsanalysis on that data.
- **Data Preprocessing :** The data needs to be preprocessed to get the fine tuned data.
- **Train CNN Network :** CNN is applied on patient dataset to train the network.
- **CNN for Prediction :** Test samples are checked against the trained network andoutput label is predicted.

3.5.3 Non-Functional Requirements: We will describe here the non-functional requirements for our system

- **Throughput:** The throughput for all the actions should be high in-order to maintain the reliability.
- **Accuracy:** System should correctly execute process, display the result i.e. given alert at that particular time accordingly. System should be able to analyze the sense of the timing as much accurate as possible.
- **Response Time:** The response time of the system should be deterministicat all times and very low, i.e it should meet every deadline. Thus, the system will work in real time for the people.
- **High Speed:** System should process requested task in parallel for various users to give quick response then system must wait for process completion.

3.5.4 Software Requirements

Databases: In this project we use MySQL database. At the time of Login or Signup, data will be fetched from the database.

Operating System: The development OS is Windows/Linux as our software works on a browser, it is not significantly dependent on OS. If the computing system has a browser and has a working internet, our product is fine to work.

1 Development Tools: For developing this product we require some developmenttools such as:
a. Anaconda.
b. Jupyter Notebook.
c. Spyder.
d. Beautiful soap, selenium

2 External Library: We use external libraries to train our models and get diagrams for analysis.Some of the libraries we use are as follows:
a. Tensorflow, Keras
b. NumPy, Pandas
c. Seaborn, Matplotlib
d. NLTK

3.5.5 Hardware Requirements: The most well-known arrangement of necessities characterized by any workingframework or programming application is the actual PC assets, otherwise called equipment. An equipment prerequisites list is regularly joined by an equipment similarity list (HCL), particularly if there should be an occurrence of working frameworks. A HCL list is tried, viable, and in some cases contradictory equipment gadgets for a specific framework or application.

In terms of development, hardware requirement is a laptop/desktop with following specifications:

- 8GB RAM.

- OS Windows/Linux.
- Intel Core i5 7th Gen+.

3.6 Project Plan

3.6.1 Module Split Up: We have divided our project into five modules, which are as follows –

1. Dataset preparation: Module in which data is organized. In our project the data is fetched fromdifferent sources and are in different formats. In this stage we ought to organize the data, convert the data into a single format and thus, build a single dataset that can be fed to the system.
2. Dataset Cleaning : Module in which data is cleaned. The dataset from the data preparation stage would be cleaned, check for errors, standardizing the values, validation of data accuracy would be done.
3. Image Pre-processing: Module in which we will write algorithm. This Module will remove unnecessary part from Image.
4. Tumor Segmentation: In this module we will implement algorithm. In tumor segmentation represents the correct identification of the

spatial location of a tumor

5. Convolutional neural network: It will detect Whether tumor is Benign or Malignant.

3.6.2 Functional Decomposition: Project functional decomposition are done in four parts which contents Register, login, Predication to tumor and Brain tumor detection. Register function will get details from user and store into database and in login function will fetch details from user and check whether it matchesWith database. Then in third part we will predicte patient has tumor or not. And in last part we will predicte the tumor type using three 3 algortihms.

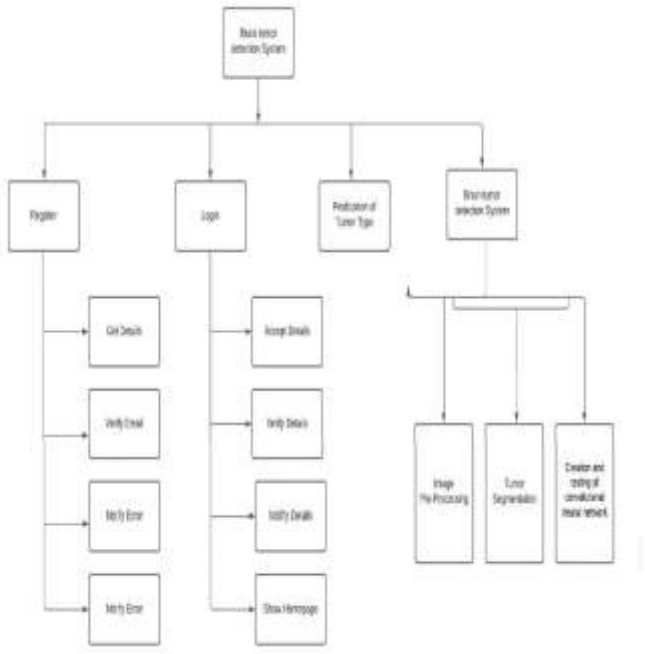


Fig3.Functional Decomposition Diagram

4. SYSTEM ANALYSIS AND DESIGN

4.1 Architecture

The system will take brain MRI images as input and then it will be passed to first module whichis image pre-processing module, In image pre-processing module we will perform skull stripping and noise removal and image enhancement. After image enhancement we will save the MRI imagewith patient data in our dataset for patient details and betterment of system, then we will pass the pre-processed image through segmentation module for segmentation of tumor and display it to patient for better understanding of tumor location. Afterwards the image passes through a classification module to classify tumor type into benign and malignant tumor.

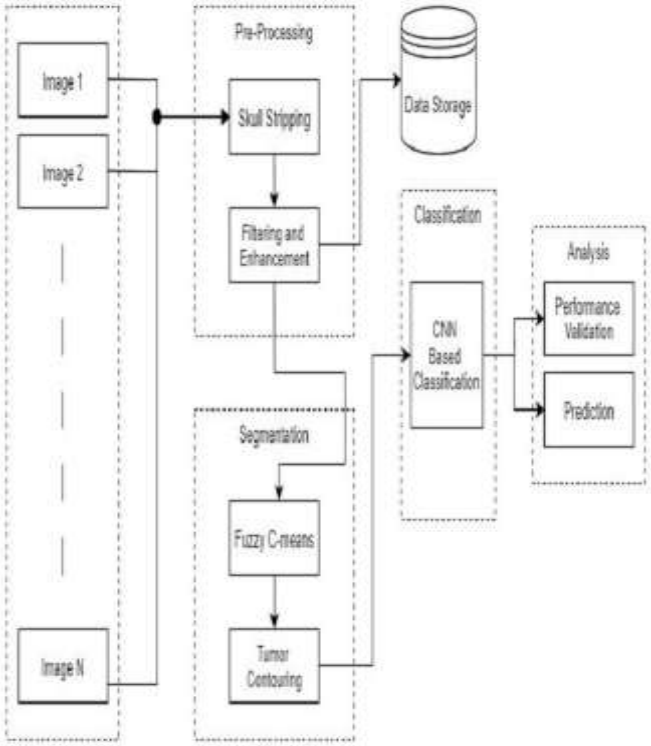


Fig. 6 System Architecture

4.2 Algorithms and Methodologies:

4.2.1 Skull Stripping : Skull stripping is image processing algorithm that will remove skull from brain MRI image. We are going to perform skull stripping using following methods:

OTSU thresholding:

OTSU thresholding is a image processing method which is used for automatic thresholding ofimage. The steps of OTSU thresholding is as follows:

1) Process input image.
2) Obtain image histogram.
3) Compute the threshold value.
4)Replace image pixels in those white regions, where saturation is greater than T and intothe black in opposite cases.

OTSU thresholding processes image histogram, segmenting the objects by minimization of the variance on each of the classes. Usually, this system produces the appropriate results for bimodal images. The histogram of such image contains 2 clearly expressed peaks, that represent completely different ranges of intensity values.

For Otsu thresholding we are going to use OpenCV library in which using function cv.threshold(), where after passing cv.THRESH_OTSU as an extra tag we can perform OTSU thresholding.

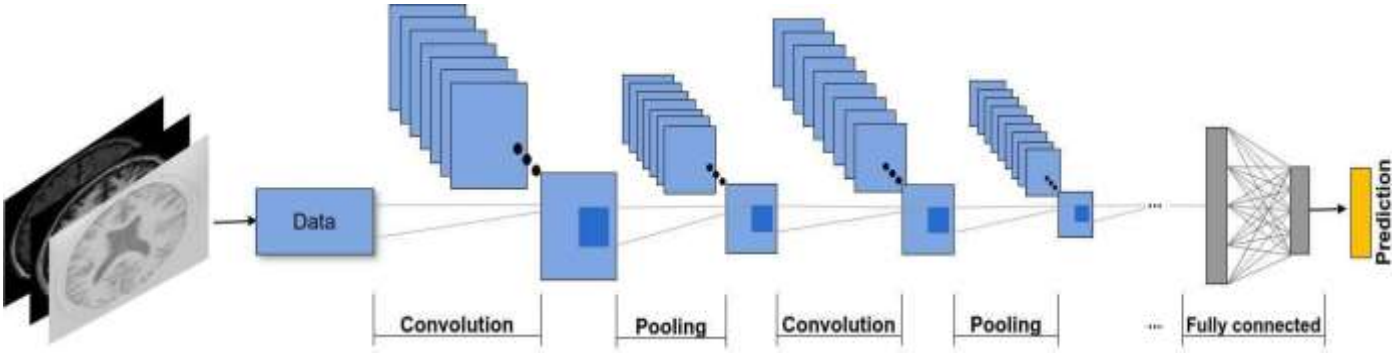
Connected Component Analysis: Connected component analysis is a image processing technique which can be used for extractionof different components of images. The first step in connected component analysis is accepting the image then converting pixels to either 0 or 1 values, then we will apply connected component labeling using OpenCV library function cv.connectedComponents().

4.2.2 Gaussian Filtering : Gaussian filter is another image processing algorithm which is useful for removing noise from image. Gaussian filter is used to blur the image and remove noise from the image. We are going to use OpenCV library in which using function cv.gaussianBlur() we will perform blur of images. In gaussian filter we will generate 2D gaussian filter, The gaussian filters uses following gaussian distribution. Where, y is the distance along vertical axis from the origin, x is the distance along horizontal axis from the origin and σ is the standard deviation.

4.2.3 Fuzzy C-means Clustering algorithm :
Fuzzy C-means clustering is a kind of clustering in which each data point can point to more than one cluster. Clustering algorithm is useful for segmentation of tumor from Brain MRI image. The pseudo code of Fuzzy c-means clustering algorithm is:
begin
Fix c,2 < c < n;
Fix ϵ(e.g. ϵ = 0.001);
Fix MaxIterations(e.g. maxIterations = 100);
Choose any inner product norm metric(eg. Euclidean distance);
Fix m, 1 < m < imt_max;
Randomly initialize V0 - v1,v2,v3
.....
,
vc cluster centers;
for t=1 to MaxIterations do
Update the membership matrix U using objective function
Calculate the new cluster Vt
Calculate the new objective function Jmtif(abs() < ϵ)
Then
Else if
End

4.2.4 Tumor Contouring:
Tumor contouring is a process of highlighting tumor portion of brain tumor in MRI images. we are going to use OpenCV library function cv2.findContours() to locate tumor in MRI image.
The pseudo code of finding contours in brain MRI image is:
Start
Upload the image;
Change image to grayscale using cv2.cvtColor();
Find canny edges using cv2.Canny();
Find Contours using cv2.findContours();
Draw contour on tumor part ;
End

4.2.5 Convolutional Neural Network :



Traditional feature learning methods rely on semantic labels of images as supervision. Theyusually assume that the tags are evenly exclusive and thus do not pointing out towards the complication of labels. The learned features endow explicit semantic relations with words. We also develop a novel cross-modal feature that can both represent visual and textual contents. CNN is a method of categorizing the images as a part of deep learning. In which we apply a single neural network to the full image. The steps in CNN are as follows: convolution, subsampling, activation and full connectedness.
Step 1: Convolution it is the primary layers that accept an input signal are called convolution filters. Convolution is a procedure where the network tries to tag the input signalby referring to what it has learned in the past.
Step 2: Subsampling Inputs from the convolution layer can be smoothened to de-crease the sensitivity of the filters to noise and variations. This smoothing procedure is labelled as sub-sampling and can be attained by taking averages or considering the maximum over a sampleof the signal.
Step 3: Activation the activation layer manages the signal flows from one layer to the subsequent Output signals which are strongly connected with past references would activatemore neurons, enabling signals to be propagated more efficiently for identify-
Step 4: Fully connected the final layers in the network are fully connected, such that the neurons of preceding layers are connected to every neuron in subsequent layers. This imitates high-Level reasoning where all feasible pathways from the input to output are measured

5. IMPLEMENTATION

5.1 Stages of Implementations :

5.1.1 Data Preparation: We will utilize BraTS 2020 dataset The picture information comprises 369 multi-contrast MR checks from glioma patients, out of which are low-grade (lgg) and some are high-grade(hgg) glioma patients. The pictures in datasets are formed by following kind of MRI strategies:T1, T2, FLAIR. The dataset we are going to use is from BraTS 2020, kaggle.

1. **Data Augmentation:** Data Augmentation can be used to increase the available data for training models, by modifying existing training dataset. Data imbalance issue can be solved using data Augmentation.
2. **Data Preprocessing:** We are going to use following pre-processing steps for every image in dataset: Convert the image from 3D MRI image of .nii file format to .jpg format using med2Image python library. Then we are going to resize the image because for creation and making of convolutional neural network we need image of same size also we are going to crop the image so that only brain remains in the image for better creation of CNN.
3. **Data Split:** We will split data in following way: For Training:80%, For Testing:20%

We are going to use a separate dataset for validation(Development) consisting of 125 images.

5.1.2 Processing :

1) Image Pre-Processing:

Initially ,We will collect the patient's details such as age, gender etc. and MRI scan of Brain. Then we will perform pre-processing on the MRI image to remove the noise and non useful parts fromthe MRI image such as the skull.

The Pre-Processing Steps are:

- Skull Stripping: Skull stripping is a process of removing skull from brain MRI image. We will implement skull stripping using OTSU thresholding and connected component analysis.
- Gaussian filtering: We will use gaussian filtering to remove noise from the image.
- Image Enhancement: Image enhancement will be used to improve image quality. For image enhancement we will use the add-weighted method.

2) Tumor Segmentation:

We will perform following operation to find out location of brain tumor in MRI image:

- Segmentation:

Segmentation process will be used to separate tumor from brain MRI image. We will use fuzzy c-means algorithm for segmentation of tumor.

- Tumor Contouring:

Contours can be explained simply as a curve, having the same color or intensity. We are going to use edge detection and findContours() algorithms to contour tumors in the brain.

3) CNN based Classification model:

We will use a trained CNN model that will predict the tumor type(E.g.Benign and Malignant).

5.2 Implementation Issues

As CNN requires a large amount of dataset for better prediction but BraTS dataset contains limited amounts of image so we are going to use data augmentation method to increase dataset images.

6. CONCLUSION

6.1 Conclusion

Thus we have successfully proposed a model that first studies the Brain MR images and predicts the tumor in brain also highlighting the tumor region and providing necessary information such that it is easily understandable by everyone. The proposed model first does preprocessing on the dataset and extract useful information to predict the presence of tumor. If the tumor is present, then the CNN architecture performs operations and classifies the tumor into Benign or Malignant types.

Our proposed system will act as strong decision supportive tool for radiologist in clinical diagnosis. By achieving high accuracy and reliability, we hope to replace the existing system in future.

6.2 Limitations

Brain tumor can be detected using CT scan images also but our system is designed to be used for MR images only due to its many advantages over CT images.MR images are less exposed to radiation as compared to CT images and also displays better information of softer tissues like the brain.

This system can be used by normal user to make decision regarding consulting and diagnosis of tumor. If tumor is detected, user must consult a doctor immediately for better understanding of the issue and its diagnosis.

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