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Brain Tumor Detection Using Convolutional Neural Network

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ABSTRACT
Brain Tumor segmentation is one of the most crucial and arduous tasks in the field of medical image processing as a human-assisted manual classification can result in inaccurate prediction and diagnosis. Moreover, it becomes a tedious task when there is a large amount of data present to be processed manually. Brain tumors have diversified appearance and there is a similarity between tumor and normal tissues and thus the extraction of tumor regions from images becomes complicated. In this thesis work, we developed a model to extract brain tumor from 2D Magnetic Resonance brain Images (MRI) by Fuzzy C-Means clustering algorithm which was followed by both traditional classifiers and deep learning methods. The experimental study was carried on a realtime dataset with diverse tumor sizes, locations, shapes, and different image intensities. In traditional classifier part, we applied six traditional classifiers namely- Support Vector Machine (SVM), K-Nearest Neighbor (KNN), Multi-layer Perceptron (MLP), Logistic Regression, Naive Bayes and Random Forest. Among these classifiers, SVM provided the best result. Afterwards, we moved on to Convolutional Neural Network (CNN) which shows an improvement in performance over the traditional classifiers. We compared the result of the traditional classifiers with the result of CNN. Furthermore, the performance evaluation was done by changing the split ratio of CNN and traditional classifiers multiple times. We also compared our result with the existing research works in terms of segmentation and detection and achieved better results than many state-of-the-art methods. For the traditional classifier part, we achieved an accuracy of 92.42% which was obtained by Support Vector Machine (SVM) and CNN gave an accuracy of 97.87%.

Introduction

1.1 Overview

Medical imaging techniques are used to image the inner portions of a human body for medical diagnosis. And medical image classification is one of the most challenging & affluent topics in the field of Image Processing. Medical image classification problems, tumor detection or detection of Cancer is the most prominent one. The statistics about the death rate from brain tumor suggest that it is one of the most alarming and critical cancer types in the Human body. As per the International Agency of Research on Cancer (IARC), more than 1,000,000 people are diagnosed with brain tumor per year around the world, with ever increasing fatality rate. It is the second most fatal cause of death related to Cancer in children and adults younger than 34 years [1]. In recent times, the physicians are following the advanced methods to identify the tumor which is more painful for the patients. To analyze the abnormalities in different parts of the body, CT (Computed Tomography) scan and MRI (Medical Reasoning Imaging) are two convenient methods. MRI-based medical image analysis for brain tumor studies has been gaining attention in recent times due to an increased need for efficient and objective evaluation of large amounts of medical data. Analysis of this diverse range of image types requires sophisticated computerized quantification and visualization tools. So, automatic brain tumor detection from MRI images will play a crucial role in this case by alleviating the need of manual processing of huge amount of data.

1.2 Brain Tumor

According to Ilhan et al. [2], a brain tumor occurs when abnormal cells form within the brain. Many different types of brain tumors exist. Some brain tumors are noncancerous (be-

1.3. CLASSIFICATION OF BRAIN TUMOR

nign), whereas some brain tumors are cancerous (malignant) and some are pre-malignant. Cancerous tumors can be divided into primary tumors that start within the brain, and secondary tumors that have spread from somewhere else, known as brain metastasis tumors
[2].

1.3 Classification of Brain Tumor

There are two types of brain tumor. One is Benign Tumor characterized as non-cancerous and the other one is Malignant Tumor- also known as Cancerous Tumor.

1.3.1 Benign Tumor

Benign brain tumors are usually defined as a group of similar cells that do not follow normal cell division and growth, thus developing into a mass of cells that microscopically do not have the characteristic appearance of a cancer [3]. These are the properties of a benign tumor:

- Most benign tumors are found by CT or MRI brain scans.
- Grows slowly, do not invade surrounding tissues or spread to other organs, and often have a border or edge that can be seen on CT scans.

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- It can be life threatening because they can compress brain tissues and other structures inside the skull, so the term 'benign' can be misleading.

1.3.2 Malignant Tumor

Malignant brain tumors contain cancer cells and often do not have clear borders. They are considered to be life threatening because they grow rapidly and invade surrounding brain tissues [4]. These are the properties of a malignant tumor:

- Fast growing cancer that spreads to other areas of the brain and spine.
- A malignant brain tumor is either graded 3 or 4, whereas grade 1 or 2 tumors are usually classified as benign or non-cancerous.
- Generally these are more serious and often more fatal threat to life.

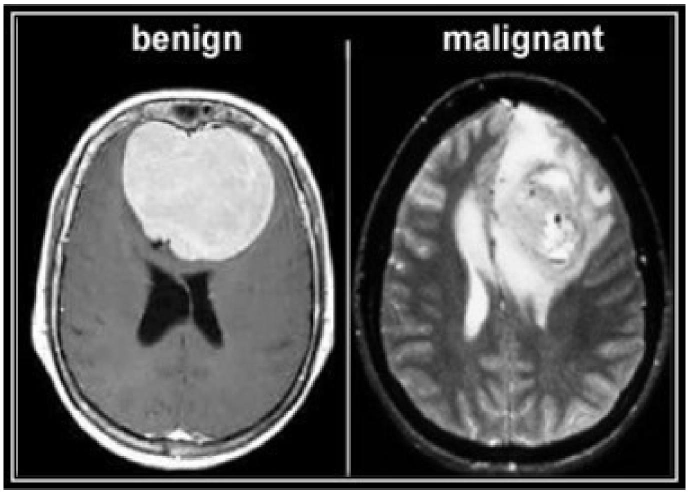

Figure 1.1: Benign Tumor (left) and Malignant Tumor (Right) [5]

Literature Review

2.1 Overview

In recent years, numerous and diverse types of work have been carried out in the field of medical image processing. Researchers from the various ground such as- computer vision, image processing, machine learning came into a place in the field of Medical Image Processing. We have studied some of the existing papers to find the most useful and advanced methods that were used in the existing articles in recent times. We worked on a total of 52 research articles. In this chapter, we will discuss thoroughly about these papers and their working procedures which are related to our work.

2.2 Reviews of the related papers

Shehzad et al. [8] proposed an algorithm to detect brain tumor from the MR images and calculate the area of the tumor. The designed algorithm claims to detect and extract the tumor of any shape, intensity, size, and location.

Working Approach:

- MRI images are converted to gray-scale images.
- Gaussian low pass filter is used to blur the image and then the blurred image is added to the original image.
- Median filter is used to remove noise.

A Statistical Analysis on Brain Tumor Segmentation Techniques

3.1 Overview

From the inception of Image processing, Medical Image is undoubtedly one of the most decisive sectors and brain tumor detection is one of the most crucial task in this field. Many researchers have worked in this field. We have studied 52 research articles which have been done for brain tumor detection and segmentation. In this chapter, we will present a statistical analysis of these research articles based on years, citations, segmentation techniques etc.

3.2 Year and Citation wise Distribution

Working on a total of 52 research articles dated from 2007 to 2018 and based on the collected information, we break down the total process of segmentation along with respective figures. We try to select the articles based on various criteria such as- citation, year, dataset, etc. but mostly focused on segmentation techniques. Apart from the single and mixed segmentation technique, we further go through the articles which adopted the Neural Network.

3.2. YEAR AND CITATION WISE DISTRIBUTION

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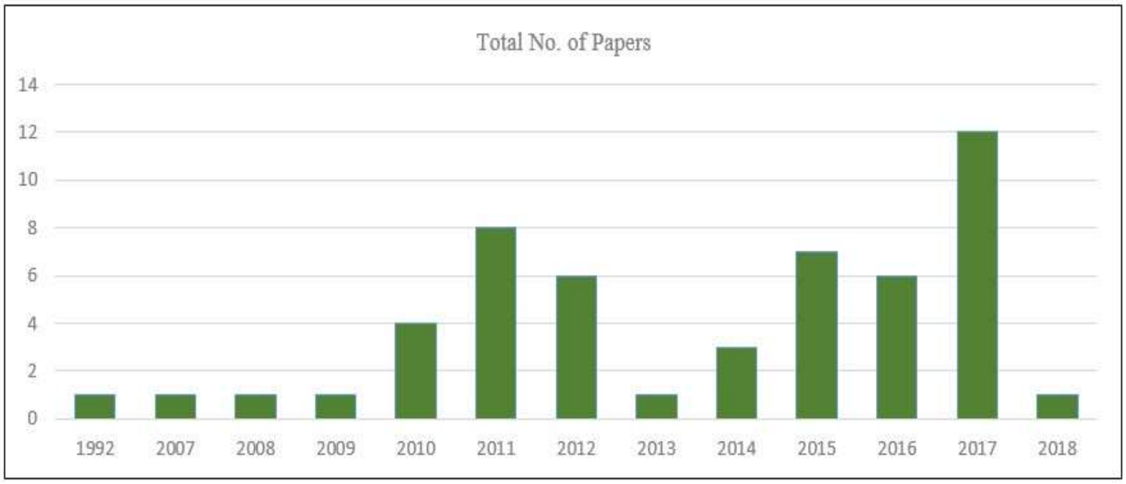

Figure 3.1: Year-wise distribution of the articles In figure 3.1 and 3.2, statistics of the articles according to years and based on segmentation types is being represented with all the accessible information.

From figure 3.1, we can see that from year 2010 to 2013 and from year 2015 to 2017, maximum number of research works have been done. And from figure 3.2, we can depict that most of the researchers adopted Neural network based detection (supervised) and clustering based segmentation (unsupervised).

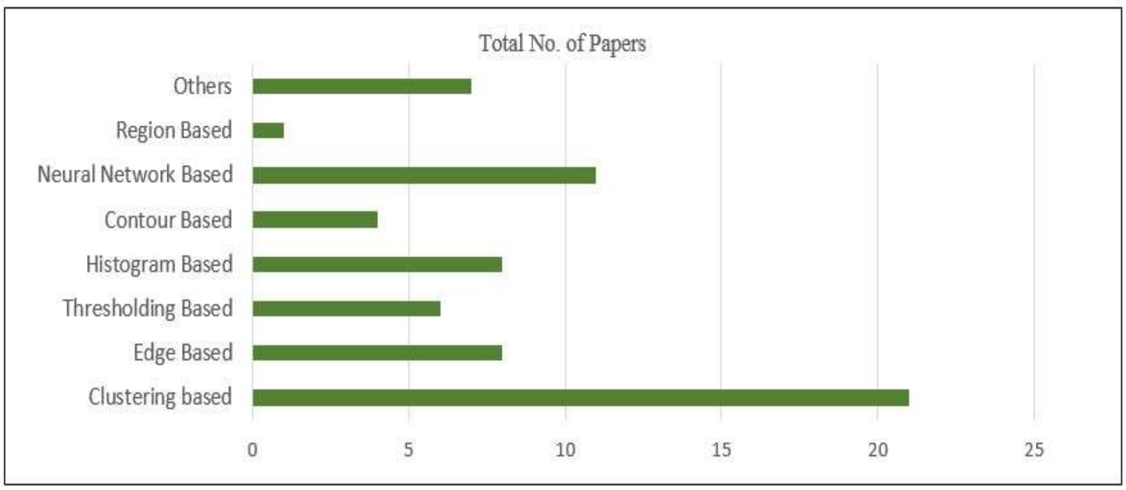

Figure 3.2: Distribution of segmentation techniques used in the articles Further, in figure 3.3, categorizing the articles based on the number of citation is described, where a total of 42 papers where the segmentation technique belongs to the primitive image processing techniques.

Background Study

4.1 Medical Image

Medical imaging means the visualization of body parts, tissues, or organs, for use in clinical diagnosis, treatment and disease monitoring. Imaging techniques encompass the fields of radiology, nuclear medicine and optical imaging and image-guided intervention.

4.2 Importance of Medical Image Analysis

Digital image processing is one of the modern and advance technology which process on the photos or videos. Nowadays x-ray is the main important application of Digital Image Processing. Before x-ray, it was very difficult to examine human bone of his body because the doctor has to cut the body skin and flesh to know about the bone of the body whether it is crack or damaged or not. In every perspective and every lane, image processing can be applied whether it is for security or for personal use. From the discovery of X-ray by Roentgen in 1895 to the present day imaging tools like Magnetic Resonance Imaging (MRI) and Computed Tomography (CT), the technology has progressed much. The advances in imaging technology will continue as time progresses. However, today the focus of systems is shifting from medical imaging focus from the generation and acquisition of images to post-processing and management of image data. This is stimulated by the need to make efficient use

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of the data that already exists. Recent progress in imaging research has shown the potential the technology can have to improve and transform many aspects of clinical medicine.

Proposed Methodology

5.1 Overview

There are two proposed model by which we can detect the abnormal cells in brain MRI. We have tried to detect the tumor using traditional machine learning algorithms and also using a convolutional neural network. In classification using traditional machine learning step, we have tried to train the proposed model using six machine learning algorithms: KNN, Logistic Regression, Multi-layer perceptron, Naive Bayes, Random Forest, and SVM. At first, we will discuss the proposed segmentation technique to distinguish the tumor. After that, we will discuss the detection of the tumor using traditional machine learning algorithm. After that, we will introduce the proposed model and thoroughly describe the all the layers related to detect the brain tumor using CNN.

5.2

Our Working Approach for Brain Tumor Segmentation

We have conducted our work for brain tumor segmentation and detection in two stages.

The stages are:

- Stage-1: Brain Tumor Detection using Traditional Classifiers
- Stage-2: Brain Tumor Detection using Deep Learning

5.2.1Stage-1:Brain Tumor Detection using Traditional Classifiers

In our first prospective model, brain tumor segmentation and detection using machine learning algorithm have been done, and a comparison of the classifiers for our model is illustrated.

5.2. OUR WORKING APPROACH FOR BRAIN TUMOR SEGMENTATION

Our proposed system of Brain tumor detection using traditional machine learning algorithm consists of seven stages:

- Step-1: Skull stripping
- Step-2: Filtering and enhancement
- Step-3: Segmentation by Fuzzy C-means Algorithm
- Step-4: Morphological operations
- Step-5: Tumor extraction & contouring
- Step-6: Classification by traditional classifiers

The results of our work accomplished satisfactory results. The main stages of our proposed model (Fig-5.1) will be illustrated in the following sections.

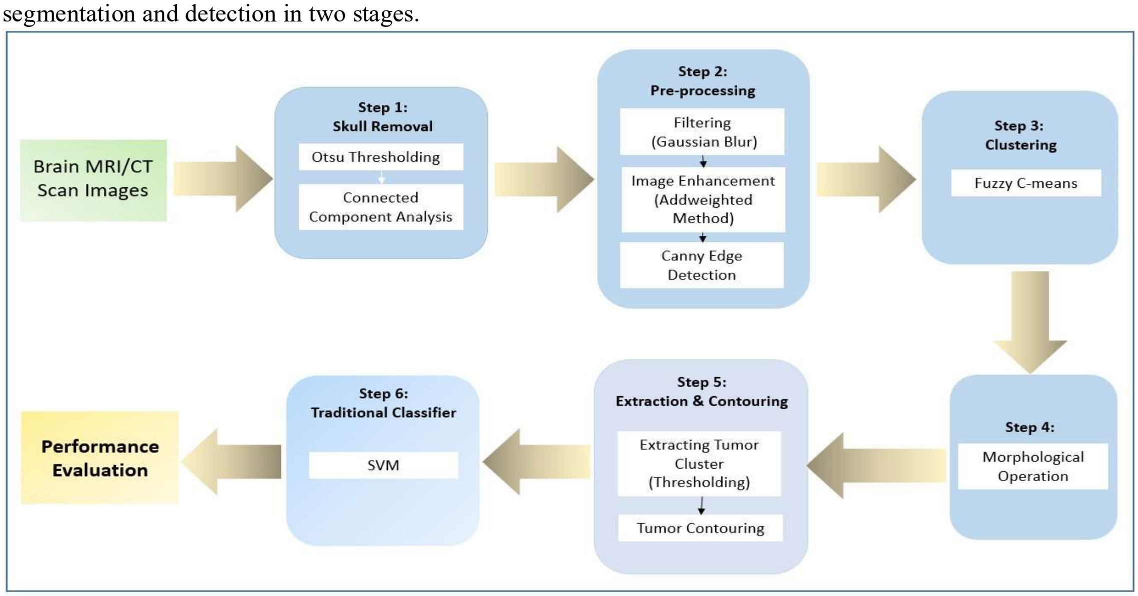

Figure 5.1: Proposed methodology for classification using Traditional Classifiers

We will comprehensively describe the proposed model of tumor segmentation and for classification using traditional Machine learning classifier, we used six classifiers and evaluated the performance.

In the later section, we will comprehensively describe the sections of the proposed methodology (fig-5.1)

5.2.1.1 Step-1: Skull Stripping

Skull stripping is a very important step in medical image processing as the background of the MRI image not containing any useful information, and it only increases the processing

5.2. OUR WORKING APPROACH FOR BRAIN TUMOR SEGMENTATION

time.

In our work, we come up with a hybrid model to remove the skull portion from the MRI images in three steps. These three steps can be elaborately explained in fig. 5.2.

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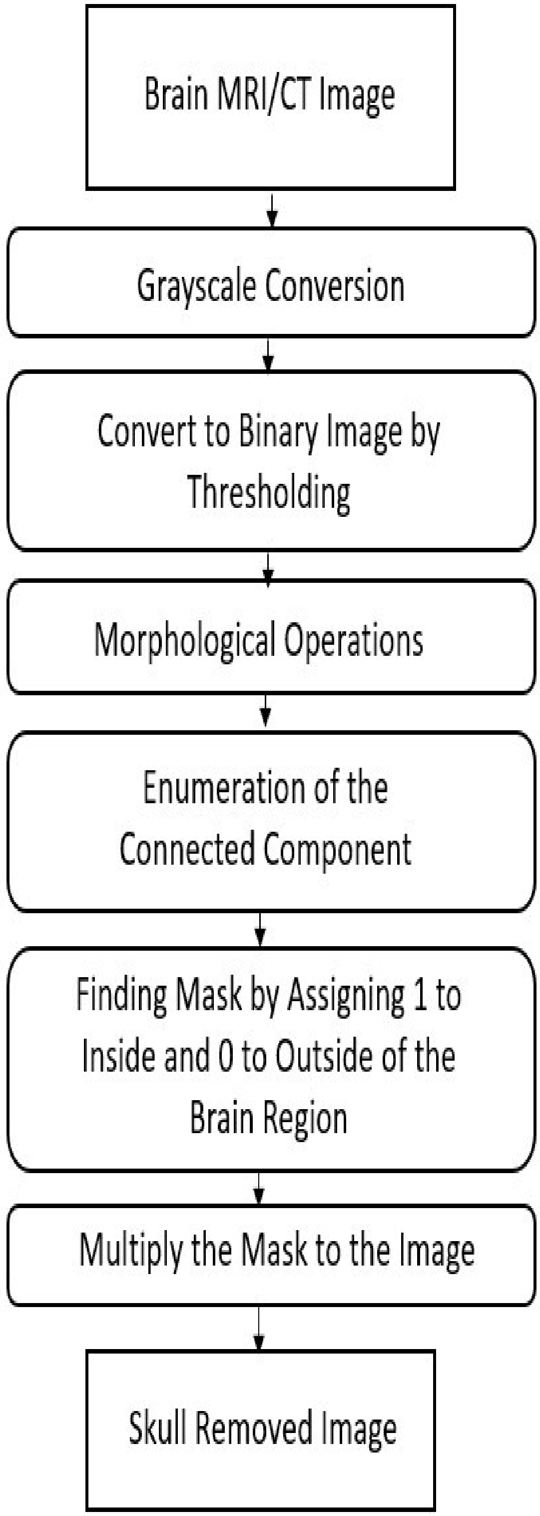

Figure 5.2: Skull stripping technique for brain tumor segmentation

- For skull removal, at first we used Otsu's Thresholding method which automatically calculates the threshold value and segments the image into background and foreground.

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Here's a **shortened version** of your **Chapter 6: Experimental Results & Evaluation**, keeping the key details intact:

Experimental Results & Evaluation

6.1 Overview

This chapter presents the outcomes of our brain tumor detection approach. We performed tumor segmentation using the **Fuzzy C-Means (FCM)** algorithm and classification using two methods: **traditional machine learning classifiers** and **Convolutional Neural Networks (CNN)**. We then compared their performance and analyzed our results against existing models.

6.2 Experimental Setup

Experiments were conducted in **Jupyter Notebook** using Python 3.6 (Anaconda), with libraries like **NumPy**, **Pandas**, and **OpenCV**. **Scikit-learn** was used for traditional models, while **TensorFlow** and **Keras** were used for CNN training on **Google Colab GPU**.

6.3 Dataset

We used the **BRATS dataset**, a benchmark for brain tumor segmentation, which includes both **tumor (class-1)** and **non-tumor (class-0)** images. The training set includes 187 tumor and 30 non-tumor MRI scans. Additionally, **Jun Cheng's dataset** with 3064 T1-weighted images from 233 patients was used to evaluate the CNN model.

6.4 Performance Measures

We evaluated the model using standard classification metrics:

- **Confusion Matrix**: Represents TP, TN, FP, FN.
- **Accuracy**: Accuracy=TP+TNTP+TN+FP+FN\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}
- **Precision**: Precision=TPTP+FP\text{Precision} = \frac{TP}{TP + FP}
- **Recall (Sensitivity)**: Recall=TPTP+FN\text{Recall} = \frac{TP}{TP + FN}
- **F1-Score**: F1=2·TP2·TP+FP+FNF1 = \frac{2 \cdot TP}{2 \cdot TP + FP + FN}
- **Specificity**: Specificity=TNTN+FP\text{Specificity} = \frac{TN}{TN + FP}

6.5 CNN Hyperparameters

Key hyperparameters used in training the CNN model:

Stage	Hyper-parameter	Value
Initialization	Bias	Zeros
	Weights	glorot_uniform
Training	Learning Rate	0.001
	Beta_1	0.9
	Beta_2	0.999
	Epochs	10
	Batch Size	32
	Steps/Epoch	80

6.6 Experimental Results

The experimental results are discussed in three parts: FCM segmentation, traditional classifier-based detection, and CNN-based detection. Detailed performance comparisons are provided in the next section.

Conclusion & Future Works

Performance analysis of automated brain tumor detection from MR imaging and CT scan using basic image processing techniques based on various hard and soft computing has been performed in our work. Moreover, we applied six traditional classifiers to detect brain tumor in the images. Then we applied CNN for brain tumor detection to include deep learning method in our work. We compared the result of the traditional one having the best accuracy (SVM) with the result of CNN. Furthermore, our work presents a generic method of tumor detection and extraction of its various features.

In the context of the full dataset, it is necessary to parallelize and utilize high-performance computing platform for maximum efficiency. We tried our best to detect the tumors accu- rately but, nevertheless we faced some problems in our work where tumor could not be detected or falsely detected. So, we will try to work on those images and on the complete dataset. Hence, we will try to apply other deep learning methods in the future so that we can get a more precise and better result.

Limitations

There are some limitations of our thesis work that we have listed in this section which we are leaving to improve in our future works.

• The BRATS dataset has only 241 images

• Worked only on 2D images.

• We could have tried more traditional classifiers to increase the accuracy.

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