Design of Image Analysis Algorithm for Brain Tumor Detection from MR Images

A Synopsis

submitted by

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1 Introduction

The introduction of information technology and advancement in the e-health care system encourages clinical supervisors or radiologists to offer a better health care to the patient. It is highly evident that, if the right treatment is offered at the right time to the patient, then the chances of survival of the patient will increase. The tumor is a life-threatening disease and its treatment consists of different stages which mostly rely on how effectively it is supervised by the radiologists.

Tumor is basically an abnormal growth of cancerous cells in the body, whereas brain tumor is classified as abnormal growth of cancerous cells in the brain. A brain tumor can be benign or malignant. A benign brain tumor has similarity in a structure called homogeneous structure and does not contain cancer cells, whereas malignant brain tumor has a non-similarity in a structure called heterogeneous structure and contains cancerous cells. The Word Health Organization (WHO) and American Brain Tumor Association (ABTA) [1] have initiated grading mechanism for tumor stages into grade I to grade IV to classify benign and malignant tumor types. On that scale, grade I and II are also called low-grade brain tumors and classifies as benign tumor types, whereas grade III and IV are called high-grade brain tumors and classifies as malignant brain tumors. The low-grade brain tumors possess a slow growth in comparison with high-grade brain tumors which possesses rapid growth.

The image processing techniques such as segmentation, enhancement, and edge detection etc. have been widely used for more than a decade. Image analysis is extremely important in the sense that, many applications are related to this field like panchromatic sharpening [2], medical image analysis [3, 4], biomedical analysis [5, 6].

The detection of a brain tumor and its classification from modern imaging modalities is a primary concern, but a time consuming and tedious work performed by radiologists or clinical supervisors. The accuracy of detection and classification of tumor stages performed by radiologists is depended on their experience only, so the computer aided technology is very important to aid with the diagnosis accuracy. In this study, to improve the performance of tumor detection, we investigated comparative approach of different segmentation techniques and select the best one by comparing their segmentation score,

the accuracy of the classification and dice coefficient index.

To improve the classification accuracy, we studied and applied different soft computing techniques such as support vector machine, self-organizing map, genetic algorithm and also investigated the combination of soft computing to get the best possible accuracy and dice coefficient index for the classification of the tumor type. We also investigated the optimization techniques for the selection of relevant features from the process of feature extraction. In this research work, we studied different features and extracted 89 features in all and selected only 33 relevant features which prominently used to classify the tumor type.

Further, to improve the accuracy, sensitivity, and specificity of the classification, we also proposed area calculation and use area of the tumor as one of the features for decision making. Finally, we develop a graphical user interface for easy observation and analysis. We also developed auto-report generation technique, which is linked to graphical user interface and produced PDF report on the analysis of the brain tumor detection within a fraction of seconds. This is the first kind of its study to develop the system of auto-report generation for easy and quick report generation.

1.1 Literature Review

The tumor is a life-threatening disease for the human being and so the early diagnosis with the highest accuracy to offer a better treatment is a primary concern. Many techniques have been proposed from the number of researchers for classification of brain tumors in Magnetic Resonance (MR) images, most notably, Fuzzy Clustering Means (FCM), Support Vector Machine (SVM), Artificial Neural Network (ANN), Genetic Algorithm (GA), Self - Organizing Map (SOM), knowledge-based techniques and expectation-maximization (EM) algorithm technique.

Aneja & Rawat [3] have proposed the algorithm for segmentation that works using FCM clustering. The segmentation performance is analyzed on the basis of cluster validity functions, execution time and convergence rate and obtained misclassification error of 0.537% using Intuitionistic Fuzzy C-Means (IFCM) technique. Zhao et al., [5] presented a Multiobjective spatial FCM, experimented on noisy images, the proposed

method evolve the number of clusters automatically. Kumar et al., [6] proposed a technique based on Fuzzy-neuro logic segmentation to develop an improved method of segmentation to detect various tissues like white matter, gray matter; cerebral spinal fluid and tumor for a given magnetic resonance image data set.

Baoping et al., [7] have proposed Fuzzy Kohonen clustering network based on high dimension fuzzy character. The algorithm developed by [7] has two steps for the operation on image segmentation, in the first step fuzzification of the pixels, is done and in the second step is about to construct 3-Dimensional feature vector of redundant images and their original images and then cluster the feature vector through Restrained Fuzzy Kohonen Clustering Network (RFKCN). Gong et al., [8] developed a segmentation technique based on Improved FCM algorithm. This technique Extended the use of tradeoff weighted fuzzy factor and a kernel metric, the tradeoff weighted fuzzy factor depends on the space distance of all neighboring pixels and their gray level difference simultaneously and a kernel distance measure employed to enhances its robustness to noise and outliers.

In this work, we focus on the evaluation of features on the different intervals to check the progress of curing of brain tumor from the observations of MR images. Damodharan & Raghavan [9] have proposed a technique using the Neural network and effectively segmented and separated normal brain tissues, such as White Matter (WM), Gray Matter (GM), and Cerebrospinal Fluid (CSF) from tumor region. They also give a comparison of accuracy, specificity, and sensitivity obtained from the classifier techniques based on K-Nearest Neighbors (K-NN), Bayesian algorithm and their proposed technique based on neural network, and obtained an accuracy of 83% using neural network based classifier. Yang et al., [10] have presented a technique using Discrete wavelet transform (DWT). This technique is proposed for the brain tumor clustering to cluster single voxel MR slices and obtained an accuracy of 94.2% with a balance error rate of 7.8%.

In this work, we calculated dice similarity index, to improve the dice similarity index is also our research objective. The validity and the superiority of the algorithm is also decided by the factor of how the algorithm produces results which is more challenging and competitive to the manual detection. Dice similarity index is the parameter to judge the comparison between the manual detection of the brain tumor from the MR images and using the algorithm. Demirhan et al., [11] presented a Self-organizing map (SOM),

wavelet and neural networks based technique for the segmentation and brain tumor detection. This method obtained an average dice similarity indexes for different tissue classes separately and achieve 91% for WM, 87% for GM, 96% for CSF, 61% for tumor, and 77% for edema. In our work, we used Berkeley Wavelet Transformation (BWT) for the segmentation, and also use feature extraction, selection, and classification for the detection of brain tumor, and through experimental analysis, the results obtained for the classification of WM, GM, CSF, and the tumor is far better than the existing techniques.

Ahmed et al., [12] proposed a Kullback-Leibler divergence (KLD) technique for the selection of relevant features. Ahmed et al., [12] Have presented a technique for posterior-fossa tumor clustering based on MR image. In this technique, relevant features for classification is selected using Kullback - Leibler divergence (KLD) measure, which is obtained using expectation maximization algorithm. Torheim et al., [13] integrated classification technique using Support vector machine (SVM) & used texture based analysis and SVM's algorithm for effective classification of dynamic contrast-enhanced MR images and claims better predictions and improved clinical factors, tumor volumes and stage in comparison with first order statistical features. To handle the non-linear distribution of real data without using any prior knowledge Guo et al., [14] have developed a segmentation technique using One-class immune feature weighted SVM.

To address the problems caused by poor image contrast, and other artifact that results in missing boundaries, Maulik [15] proposed a technique for segmentation using a Genetic algorithm (GA). The same is also addressed in our research work using preprocessing by means of image enhancement and skull-stripping. Sachdeva et al., [16] presented a technique based on the Artificial neural network. This technique presented a multiclass brain tumor classification, segmentation and feature extraction using a dataset of 428 MR images and obtained classification accuracy from 77% to 91%. To handle the difficulties raised by noises, low contrast and bias field in brain tumor segmentation from MR images, Ji et al.,[17] uses Fuzzy local Gaussian mixture model. Miah et al., [18] presented a Neural network based approach for the detection of brain tumor from the MR images. Miah et al.,[18] presented a technique for detection of tumor tissues from brain MR images based on different techniques of feature extraction, which is trained by the neural network for optimization. Cui et al., [19] proposed a Localized fuzzy c-means

clustering based segmentation. In this method segmentation and bias field estimation are simultaneously achieved by minimizing the global fuzzy energy and also reduce the impact of noise.

Wang et al., [20] developed Active contour models based segmentation to deal with the problem of intensity inhomogeneities in image segmentation. Chaddad [21] presented a Gaussian mixture model (GMM) for the segmentation and using principal component analysis (PCA) and wavelet based features, the performance of the GMM feature extraction is enhanced. Chen et al., [22] have proposed a Multiple-Kernel Fuzzy C-Means. To fuse different pixel information in image-segmentation problems, so, different pixel information represented by different kernels is combined in the kernel space to produce a new kernel. Sulaiman & Isa [23] have presented an Adaptive Fuzzy-K-means Clustering based segmentation technique for the brain tumor detection and providing a better segmentation performance for various types of images and various number of segmented regions.

Jafari-Khouzani [24] have presented a Feature-based non-local means technique specially designed for the up-sampling of low-resolution MR images by means of improving Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM), and computation time. Madhukumar & Santhiyakumari [25] have proposed an integrated system for the brain tumor segmentation from the MR images using K-means and fuzzy C-means. This study addresses the problem of tumor detection by comparing the performance of K-means and FCM and proves that K-means of segmentation technique gives better results compared to FCM. Aggarwal & Agrawal [26] have proposed a Discrete Wavelet Transformation (DWT) based brain tumor detection technique from the MR images. This technique uses first and second order statistic features for evaluating the progress of brain tumor detection from MR images.

Deepa & Arunadevi [27] have proposed an Extreme learning machine based technique for the brain tumor segmentation. This method based on extreme learning machine classification technique obtained an accuracy of 93.2%, the sensitivity of 91.6%, and specificity of 97.8% for the analysis of 3D MR images. Yazdani et al., [28] developed an Automatic method for the identification of brain tumor from MR images. This method uses three steps for the analysis of the tumor type: histogram based segmentation, feature

extraction and finally classification using SVM and is specially designed to deal with the issues such as noise, bias field, partial volume effect, and complexity of the images. Telrandhe et al., [29] presented a K - means of clustering and classification based on SVM. In this method, the area calculation from the extracted tumor is used for the decision on the tumor type. Halder & Dobe [30] have proposed a Fuzzy clustering based feature selection and SVM-based classification. In this technique, features are extracted, which is optimized using fuzzy based clustering algorithm and then finally classification is done using SVM.

2 Findings from the Literature Review

From the literature review discussed in section 1.1 following findings are observed:

1. Accuracy for the brain tumor detection from MR images are around 90% only [9, 10, 27].
2. Segmentation operation is mostly based on FCM and FCM related techniques [3, 6, 25, 29, 30]
3. Low dice similarity index coefficient, so less trustworthy compared to manual detection by the radiologists or clinical experts [11].
4. Only a few or limited features are extracted for the analysis and decision making on the tumor type [12, 18, 24].
5. Feature selection but without optimization technique [12, 18, 24].
6. In most of the research, classification techniques are more complex as more mathematical calculations are involved in classifier due to missing of feature selection and optimization [12, 18, 24].
7. If the MR images are available in compressed domain then its effect and parameter/performance analysis is not done.
8. No auto-report generation technique in any of the research.

3 Motivation

Cancer is a life-threatening disease and it is also evident that if the early treatment is offered to the patient with the right combination of the therapy, then the chances of the survival of the patient is increased. During the last one decade lots of research has been produced and investigated, number of researchers have developed new techniques to segment, detect and classify tumor types using the modern techniques based on Support Vector Machine (SVM), Self-Organizing Map (SOM), Fuzzy Clustering Means (FCM), Genetic Algorithm (GA), Principal Component Analysis (PCA) etc. In spite of many researches has developed to detect tumor from the MRI or from other modern imaging modalities, no researches are fully automatic and adoptable. Apart from this, no researches have been investigated to produce auto-report, probably this is the first attempt to investigate auto-report generation system, integrated to assist radiologists or clinical supervisor for quick diagnosis analysis. The purpose of this research work is to extract relevant information from the segmented tumor region and classify healthy and infected tumor tissues for a large database of medical images. The results of this research are helpful in classifying benign and malignant tumors, fast and accurately and thus, improving the diagnosis of tumor slices. From the literature findings, we are motivated to address the following

1. To improve segmentation score and dice similarity index coefficient
2. To extract more features and select only relevant features
3. To improve the classification accuracy
4. To check the performance of the proposed algorithm on compressed images
5. To develop auto-report generation system for the quick diagnosis analysis

4 Research Objective and Scope

In spite of lots of research has been reported and investigated by many researchers using the modern techniques, it seems that there is still scope for the improvement of the actual MRI based brain tumor segmentation, detection, and classification.

Based on the literature review & critical finding, the objective of the proposed thesis work is given as follows.

1. To develop a segmentation method which provides the highest degree of segmentation score, dice coefficient, characterization of tumor tissues (white matter, gray matter, and edema), and other performance parameters from MR images of the brain tumor.

2. To evaluate the segmentation accuracy of these methods against a gold standard produced by manual segmentation and other available techniques.

3. To propose segmentation with a classification scheme optimize using feature selection for categorizing the type of brain tumor classes.

4. To evaluate the segmentation performance for the MR images available in compressed form so it will help in the advancement of e-health care technology and also to developed an auto-report generation technique for the quick diagnosis analysis.

5 Organization of the Thesis

The thesis is organized into seven chapters. All the chapters focus on the different aspect related to the investigation of the brain tumor detection (BTD). The organization of this thesis is as follows;

Chapter 1 provides the introduction to the work carried out in this thesis. The detailed literature review, finding from the literature review, motivation, and research objectives are discussed in chapter 1.

Chapter 2 analyzes the medical background of the current study. It starts with a basic introduction and continues with a description of incidences, treatment available, surgery, radiotherapy, and chemotherapy. It also discuss the modalities used for imaging the brain tumor and their comparison with other available modalities discuss their strength and weaknesses. The acquisition of MRI sequences with their detailed modalities and timing constraints are also explained.

Chapter 3 presents the importance of preprocessing of medical images. It discusses the skull-stripping operation and their impact on brain tumor segmentation and presents the overview of image enhancement and finally along with subsections discusses the detailed analysis of image enhancement on MR images with their performance metrics and their impact on brain tumor detection.

Chapter 4 presents the segmentation method for the brain tumor segmentation from MR images and results of the current study. It starts with an overview of segmentation method, their areas of applications in the different fields of interest and continues with the discussion of different techniques for segmentation. Finally, focus on our proposed segmentation technique which is based on BWT with their complete mathematical notions, and the segmentation results and also discusses the merits and weaknesses of each segmentation method by means of segmentation score.

Chapter 5 presents the methods developed in this study for feature extraction and their optimization by means of retaining only relevant features, It starts with an overview of different feature extraction methods with their complete mathematical notions and continues on the impact of some of the features on Brain Tumor Detection (BTD). It discusses how the area of the tumor is calculated and its impact on the decision of tumor type. In this research work, we used double classification technique to classify the tumor type, one decision is influenced by the features and second is influenced by the area of the tumor. Feature selection and available methods used for feature selection with their detailed algorithm are also discussed.

Chapter 6 presents the classification technique for the classification of the type of brain tumor from MR images. This chapter discusses performance evaluation metrics which is one of the important criteria to judge the superiority of the algorithm, It gives a detailed comparison of the proposed classifier with the other state of the art techniques and also discusses their accuracies with and without feature extraction. It also discusses the implementation of the proposed algorithm for the brain tumor detection from the MR images and also focuses on their design layout using graphical user interface. It also presented experimental results and the impact of compression on the proposed algorithm with their detailed performance analysis parameters for segmented tissues.

Chapter 7 gives an overall summary, the conclusion of the proposed work, its limi-

tations and offering suggestions for future research.

6 Contribution of the Thesis

The proposed work in this thesis is novel and provide a scope for the treatment of a life threatening disease with the help of MR images. The contribution of thesis are as follows;

- Performs comparison on different image enhancement techniques and select the best one (on the basis of performance parameters) for taking care of artifacts, noises and to improve the quality of the MR images. To improve the performance of the segmentation, skull - stripping operation using threshold is also developed.
- Presented a Berkeley Wavelet Transformation (BWT) for the purpose of brain tumor segmentation from the MR images. This is the only case where BWT technique is used for the brain tumor segmentation. The segmentation score is also calculated, to evaluate the performance of BWT over the other available state of the art techniques. The complete analysis using experimental results using different available methods is also explained. The average segmentation score obtained for the brain tumor segmentation from MR images are **0.60**, **0.76**, **0.81**, and **0.88** for the watershed based segmentation, FCM based segmentation, DCT based segmentation and BWT based segmentation respectively.
- Presented a technique for feature extraction and selection. Feature selection is used to retain only relevant features and so it reduces the mathematical complexity of the classifier. Our proposed technique uses a Genetic algorithm (GA) for the optimization of the features. To improve the diagnosis decision and accuracy, the area of the tumor is also calculated and included as one of the feature for decision making by the classifier.
- Presented the contribution for the classification of the tumor type. Our work achieved **97.77%** accuracy with feature extraction and **92.48%** without feature extraction.
- Presented the overall design algorithm and implementation for the proposed work. Auto-report generation system to produce the diagnosis report for the purpose of

the quick decision by the radiologists or clinical supervisor in Portable Document Format (PDF) is also developed.

7 Conclusions

The brain tumor segmentation and detection is performed using Berkeley Wavelet Transformation, and its results are also compared with the other available methods using segmentation score. For more authentication on the diagnosis analysis, features are extracted and to reduce the mathematical complexity of the classifier, only relevant features are selected. We introduce area of the tumor as one of the feature and include its mathematical notion for the classifier to classify the tumor type. Finally, to ease with diagnosis decision and quick analysis, the auto-report generation technique is developed. To improve the overall visualization of the proposed system, the simplified graphical user interface is also developed.

To make the system more convenient and user-friendly, a graphical user interface (GUI) is developed. The GUI based system is designed in such a way so that it will enhance the overall visualization of the results. The GUI is also equipped with auto-report generation technique, which is actually linked to Tex file (LaTeX program). All the relevant results which are necessary to assert the decision on tumor type by the radiologists or clinical supervisors is automatically produced in the auto-generated PDF document. The decision on the tumor type i.e. benign or malignant is also facilitated through the classifier as well as using area calculation. Here for the analysis point of view, it is assumed that, if the tumor area is less that $8\ mm^2$, then the identified tumor is benign, otherwise it is malignant. The two-way classification system using SVM based classifier and the area calculation ensures the system is more reliable and highly efficient.

The developed GUI is also worked very fast and produces results within a fraction of seconds. The auto-report generation technique of GUI is also produced PDF report within 2-5 seconds, depends on the complexity of input MR image. The only drawback of the proposed system is, auto-report generation technique extracts all the information from CSV (Comma Separated Value - Excel file), but matlab produces XLS file (CSV file produced by the matlab is not compatible with LaTeX program), so manual conversion

from XLS to CSV needs to be executed before producing the report through an auto-generation feature of GUI.

The experimental results achieved 97.77% accuracy, 98.98% sensitivity, 94.44% specificity and 98.49% average dice coefficient index, demonstrating the effectiveness of the proposed technique for identifying normal and abnormal tissues from MR images. Our results lead to conclude that the proposed method is suitable to integrate clinical decision support systems for primary screening and diagnosis by the radiologists or clinical experts.

To make the advancement in the e-healthcare system, the experimental results are also examined for the MR images available in the compressed form, and it is verified that the effect on the performance parameters is very small, and almost negligible. This will help us to transmit the results and diagnosis analysis from one medical center to another medical center around the globe on limited bandwidth. This advancement will lead us to provide complete healthcare system to the patient.

Further, our existing technique of auto-report generation may not be fully automatic, as manual conversion between XLS to CSV is needed to execute before generation of the report. To make the system completely automatic we need to investigate automatic conversion between XLS to CSV with some more guided interrogation and this will require fundamental work in existing techniques.

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8 Publications (From the Ph.D. work)

8.1 Papers in Refereed Journals - SCOPUS Indexed

1. **Accepted:** **Nilesh Bhaskarrao Bahadure**, Arun Kumar Ray, and Har Pal Thethi, "Image analysis for brain tumor detection using GA-SVM with auto-report generation technique", *International Journal of Biomedical Engineering and Technology*, , (2017)

2. **Nilesh Bhaskarrao Bahadure**, Arun Kumar Ray, and Har Pal Thethi, "DCT Enabled Lifting Wavelet Transformation Based Image Analysis for Brain Tumor Detection and Extraction", *International Journal of Engineering and Technology*, **9**, pp. 532–540 (2017)

3. **Nilesh Bhaskarrao Bahadure**, Arun Kumar Ray, and Har Pal Thethi, "Image Analysis for MRI Based Brain Tumor Detection and Feature Extraction Using Biologically Inspired BWT and SVM", *International Journal of Biomedical Imaging*, **2017**, pp. 1–12 (2017)

8.2 Papers in Refereed Journals - SCIE & SCOPUS Indexed

1. **Nilesh Bhaskarrao Bahadure**, Arun Kumar Ray, and Har Pal Thethi, "A Comparative Approach of Brain Tumor Detection using SVM, DCT and Huffman Coding in Compressed Domain", *Current Medical Imaging Reviews*, **13**, Issue 3, (2017)

8.3 Presentations in Conferences

1. **Nilesh Bhaskarrao Bahadure**, Arun Kumar Ray, and Har Pal Thethi, "Feature Extraction and Selection with Optimization Technique for Brain Tumor Detection from MR Images", *In Proceedings of IEEE International Conference on International Conference on Computational Intelligence in Data Science,* Chennai, Tamil Nadu, India, June 2 - 3, 2017.

2. **Nilesh Bhaskarrao Bahadure**, Arun Kumar Ray, and Har Pal Thethi, "Performance Analysis of Image Segmentation Using Watershed Algorithm, Fuzzy C - Means of Clustering Algorithm and Simulink Design", *In Proceedings of IEEE International Conference on Computing for Sustainable Global Development,* New Delhi, India, March 16 - 18, pp. 1860 – 1864, 2016.

3. **Nilesh Bhaskarrao Bahadure**, Arun Kumar Ray, and Har Pal Thethi, "Performance Analysis of Soft Computing and Image Processing based Image Segmentation", *In Proceedings of International Conference on Engineering Technologies and Big Data Analytics (ETBDA'2016),* Bangkok, Thailand, January 21 - 22, pp. 30 – 34, 2016.