Review of Brain Tumor Segmentation, Detection and Classification Algorithms in fMRI Images

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Abstract—Nowadays Brain tumor detection in early stage is necessary because many people died due to unawareness of having a brain tumor. On the other side influence of machine learning becomes larger and larger in our lifes and our society, artificial intelligence might also start playing an important role in medical diagnosis and support of doctors and surgeons. This paper is focused on review of those papers which include segmentation, detection and classification of brain tumors.

The common procedure for an algorithm which aims to classify brain tumors on fMRI or MRI scans is:

Preprocessing the image for example by removing noise, then segmenting the image, which yields the region which might be a brain tumor, and finally classifying features such as inten-sity, shape and texture of this region. Many machine learning approaches towards brain tumor detection have already been made. However, these approaches, even though yielding good results, are not used yet. Therefore this research topic remains important and still requires attention.

Index Terms—fMRI, brain tumor, machine learning

I. INTRODUCTION

Brain tumors are possibly the most dangerous and deadly type of cancer. It is estimated for this year that around 17,000 people will die from brain or spinal cord tumors and around 24,000 people will be diagnosed with such a tumor in the USA [1].

The term ”brain tumor” describes the abnormal growth of cells in the brain. There are two main types of brain tumors: malignant tumors and benign tumors [2]. Benign brain tumors are non-cancerous which means that they do not spread out to adjusting tissue or to other parts of the body. They are usually treated by surgery or radiation therapy, if it is necessary to treat them, which is not always the case. As they do not spread out and grow as fast as malignant tumors they usually have a clear boundary and can be removed by surgery such that reoccurrence of the tumor is unlikely. Symptoms of such brain tumors are for example headaches, nausea and problems concerning balance, hearing and vision. The 5-year survival rate for benign tumors varies between 80% and values close to 100%. Malignant brain tumors are cancerous and grow much faster than benign tumors, this type of tumor is therefore regarded as more aggressive and far more life threatening. The 5-year survival rate for this kind of tumor varies between 30% and 40%. The relative 5-Year Survival Rate for different ages and tumor types can be seen in Table 1.

TABLE I. 5-YEAR RELATIVE SURVIVAL RATE

Type of Tumor	Age		
	20-44	45-54	55-64
Low-grade (diffuse) astrocytoma	68%	44%	22%
Anaplastic astrocytoma	54%	32%	14%
Glioblastoma	19%	8%	5%
Oligodendroglioman	88%	81%	68%
Anaplastic oligodendroglioma	71%	61%	46%
Ependymoma/anaplastic ependymoma	92%	89%	86%
Meningioma	87%	77%	71%

These numbers depend on factors like age and gender of the patient and also location and size of the tumor. Especially the size of the tumor is a big factor which decreases the survival rate with increasing size. This makes it so important to detect brain tumors in an early stage when the tumor is still smaller. This can be the factor which decides between life and death of the patient. But detecting brain tumors in early stages can be very difficult for the human eye. This should motivate researchers all over the world to explore this important topic and propose machine learning algorithms which aim to detect and classify brain tumors.

Currently doctors use functional magnetic resonance imaging (fMRI) or magnetic resonance imaging (MRI) to detect and classify tumors. fMRI and MRI are two methods of brain scans which both have a very high spatial resolution, they are therefore well fitted for this issue. Experts use the following three features of a region to detect or classify a brain tumor: intesity, shape and texture. These features are also made use of in machine learning algorithms for the classification and detection of brain tumors in fMRI or MRI images. This paper is supposed to give the reader a comprehensive survey on approaches that have been made on this topic.

II. LITERATURE SURVEY

The following literature survey will be divided into two parts: Part one is Segmentation, the result of segmentation is the infected region. Part two is Detection and Classification of Brain Tumors. Detection yields a binary output which either says: ”No Brain Tumor” or ”Brain Tumor”. In classification the tumor is further classified in e.g. malignant or benign brain tumors. Approaches that combine both will be found in the second part of this section.

A. Segmentation of Brain Tumors

N. Nandha Gopal et Al. [3] proposed a method whose aim is to extract the tumor region from the image. This is done by

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first preprocessing and enhancing the image and then segmenting it by using Fuzzy C Means either with genetic algorithm, particle swarm optimization or just Fuzzy C means. The Fuzzy C Means with particle swarm optimization approach reached an accuracy of 92.3% while the Fuzzy C Means with genetic algorithm approach reached 74.6%.

Another novel brain tumor segmentation approach was made by A. R. A. Abdulraqe et Al. [4]. First they applied an automatic threshold to segment the image. This threshold was chosen based on the histogram of the MR image. After that they located the tumor based on the maximal count of pixels vertically and horizontally, this technique yields a precise rectangle in which the tumor is located.

Aye min et Al. [5] also proposed a brain tumor segmentation approach. To pre-process the fMRI image a median and a Wiener filter were applied separately, after that the filtering results were merged. Then adaptive K-means clustering was used to segment the image. Adaptive K-means is used here instead of normal k-means because setting the K to a fixed value is a bias which is too strong. And finally morphological operators were used to segment the brain tumor region. In segmenting brain tumors in flair images the proposed algorithm reached an accuracy of 98.30%.

Navpreet Kaur et Al. [6] performed self-adaptive K-means Clustering to segment brain tumors. The following steps were part of the pre-processing: First a median filter was applied to remove noise, skull stripping was performed using the brain surface extraction algorithm. Skull stripping is the process of removing all non-brain tissue from the fMRI or MRI image. This is necessary because eyes or bones can have a high intensity value and maybe also tumor like shape which can make the tumor detection more difficult. After that Salt and Pepper noise was removed. Then self-adaptive K-means clustering is used to segment the image and finally a sobel edge detector is used to furthermore extract boundaries.

Another novel brain tumor segmentation approach was proposed by Naouel Boughattas [7] et Al. and it uses multi kernel learning for feature selection and classification. The multi kernel learning is used to weight the importance of features which are to be classified by a support vector machine. In the training step they created a database of features of boundary voxels between tumors, edema and healthy tissues, which were labelled by an expert. Now the MKL-SVM is trained on this dataset. After that voxels can be classified. Since the resulting segmentation always contains small errors, post-processing is done by using morphological operators and by again applying the MKL-SVM algorithm on a reduced area around the segment.

B. Detection and Classification of Brain Tumors

Nilesh et Al. [8] approached the brain tumor detection problem as follows: They preprocessed the MR images by applying adaptive contrast enhancement based on modified sigmoid function, after that they performed skull stripping, which is the process of removing non-brain tissues in the MR image, by combining thresholding with binary masking. The preprocessed image was then segmented by using a threshold again. Then the resulting binary image was further processed using erosion to remove white pixels that do not belong to the infected region. Now the result is applied as a mask on the original image. Finally the gray level co-occurrence matrix was computed and the extracted features were classified by a support vector machine. The classification by SVM resulted in an accuracy of 96.51%.

Another approach for identifying the grade of a tumor was done by M. Monica et Al. [9]. First noise was removed from the image by using a PCNN, after that the image was segmented by using Fuzzy C means and features were extracted. Then the features were classified by a na¨ıve bayes classifier. This method reached an accuracy of 91%.

T. Chithambaram et Al. [10] proposed a method that uses genetic algorithms and artificial neural networks to classify brain tumors. First the tumor regions are market by the content based active contour model. From these regions intensity and texture features are extracted, feature selection is done by the genetic algorithm which optimizes the feature selection. Now the features are classified by an artificial neural network or by a support vector machine. The SVM had an accuracy of 91.7% and the ANN of 94%.

Anil Singh Parihar [11] uses a convolutional neural network to classify brain tumors into high-grade glioma and low-grade glioma. A convolutional neural network is a type of artificial neural network that is used to classify images. Its structure is inspired by the organisation of neurons in the visual neurons of animals. In this approach such a CNN is trained to recognize and classify brain tumors. Before feeding the image in the CNN it is preprocessed by normalizing it based on the intensity.

Animesh Hazra et Al. [12] proposed an algorithm for brain tumor detection based on segmentation. They first preprocessed the image by converting it from RGB to gray and then applying a median filter to remove noise. Furthermore they would use image enhancement in case there is poor contrast in the image. After this stage they performed edge detection by using either sobel, canny or prewitt edge detectors. Then they segmented the result using either single, multiple or various thresholding. The binarized image is then clustered via k-means algorithm.

In the approach of Vidya Dhanves et Al. [13] the brain tumor region was first segmented and then classified. First the image was converted into a contrast image, after that it was preprocessed using the morphological operators erosion and dilation to perform skull stripping and the median filter to remove noise. The preprocessed image was then segmented by k-Means clustering and the segmented region classified by an object labeling algorithm. This method reached an accuracy of 75.51% and a True-Positive rate of 96.67%.

Nitish et Al. [14] proposed an algorithm which classifies tumors into four different tumor classes. The features, which were extracted using the gray level co-occurrence matrix, were classified by a two layer feed forward neural network which was optimized by the Levenberg Marquart nonlinear optimization algorithm. An accuracy of 97.5% was reached.

In the approach of Jothi G. et Al [15] many different feature selection algorithms were used after the tumor region was found by using threshold segmentation and region growing. The feature selection algorithms are: Supervised Tolerance Rough Set-PSO based Relative Reduct (STRSPSO-RP), Supervised Tolerance Rough Set-PSO based Quick Reduct (STRSPSO-QP), Artificial Bee Colony (ABC), Cuckoo Search Algorithm (CSA), and Supervised Tolerance Rough Set-Firefly based Relative Reduct (STRSPSO-RP). The selected features were then classified by a J48 classifier.

Ch. Amulya et Al. [16] used SURF and SIFT features which were then classified by a KNN classifier to detect brain tumors in MR images. The results are that SURF – SIFT features yield an accuracy of 96.22%, whereas SURF features alone reach an accuracy of 94.33%. However the time needed for SURF-SIFT features is much higher than the time needed for only SURF features. When SURF and SIFT features were classified by the KNN classifier an accuracy of 96.22% was reached.

Ankit Vidyarthi et Al. [17] compared a variety of different algorithms for classification and feature extraction and selection. The combination with the best results was the Gabor-wavelet transformation for feature extraction, the Cumulative Variance Method for feature selection and a back-propagation neural network for classification. An accuracy of 97% was reached.

Sonali et Al. [18] proposed an algorithm that classifies tumors into Normal, Benign and Malignant. Further, malignant tumors were divided into glioma and meningioma. First principal component analysis was used to extract features, then they were classified using a probabilistic neural network. The algorithm was trained on 70 samples and tested on 35. An accuracy of 97.14% and 100% was reached.

Qurat-ul Ain et Al. [19] first extracted the brain tumor region by using K-means clustering and edge detection. The extracted region was then classified using a na¨ıve bayes classifier which reached an accuracy of 99%.

E. F. Badran et Al. [20] made the following steps to identify malignant and benign brain tumors: First the image was pre-processed, then segmented, after that features were extracted and then a neural network classified the features. For the location of the tumor region of interest techniques were applied.

In the approach of Sneha Khare et Al. [21] a genetic algorithm is used to segment the image. The segment is then further processed using a curve fitting method. Now features are extracted from the segment and classified with a support vector machine.

K. B. Vanishanvee et Al. [22] used a proximal support vector machine (PSVM), which is supposed to be faster and computationally more effective than the standard support vector machine, to classify features of the gray level co-occurrence matrix of the segmented image. Features were selected by principal component analysis. The overall accuracy reached by this approach is 92% whereas using normal support vector machine yields an accuracy of 82%.

Sudha B et Al. [23] used various artificial neural networks to classify extracted features from the gray level co-occurrence matrix and the gray level run length matrix of the brain scan. The features were chosen according to a fuzzy entropy measure. This approach reached an accuracy of 96.7%.

Another method was proposed by Gladis et Al [24]. This method uses a support vector machine to classify intensity, texture and shape features which were selected via principal component analysis and linear discrimination analysis.

Dipali M. Joshi et Al. [25] used a neuro-fuzzy classifier to classify features from the gray level co-occurrence matrix of the segmented input image.

Another classification approach was proposed by Ahmed Kharrat et Al. [26] who used a support vector machine to classify via wavelet and spatial gray level dependence method (SGLDM) extracted features. A genetic algorithm was used for the parameter tuning of the support vector machine. This approach reached a maximal accuracy of 98.14%.

Saumya Chauhan et Al. [27] proposed an algorithm that detects a brain tumor and furthermore classifies the tumor either as malignant or as benign. First a median filter was used to remove noise from the image, then the gray image was converted to RGB and further to l*a*b color space. The resulting image was segmented using colour based k-means clustering. After clustering features were extracted from the region with most indexes. Feature extraction was accomplished by using the gray level co-occurrence matrix, the histogram of gradients and the Canny edge detecter. These features were then classified by the IBkLG algorithm (Instance Based K-Nearest using Log and Gaussian weight kernels classifier), which classifies the images with an accuracy of 86.6%.

Another promising approach was proposed by Salim Ouchtati et Al. [28] which does not only detect brain tumors but also determines the location of the tumor in the brain. The pre-processing was done by reshaping the images to 128x128 pixels and normalizing then. In the feature extraction step the image was devided into 64 window of the size 16x16 and the central moments of the order one to three were extracted as features for the histogram of every window. These features were then feed into a neural network and classified. This classification yields an accuracy of 88.333%.

F. P. Polly et Al. [29] proposed an algorithm that detects brain tumors but furthermore also distinguishes between high-grade glioma and low-grade gliomas, where HGG are more aggressive and deadly tumors. To yield binary images Otsu binarization was used, this method applies a threshold on the image depending on the variance of the image. After that the binary image is segmented by using k-means clustering. Now features were extracted via discrete wavelet transform. In order to reduce all the extracted features to the most significant features principal component analysis was used. Finally the extracted features were classified by a SVM. According to the authors this methods yields an accuracy of 99% for detection and classification.

III. CONCLUSION

Various approaches towards brain tumor detection and classification have been summarized and presented in this paper. There are various methods which have been used, from genetic algorithms used to optimize the segmentation, to the method of convolutional neural networks to just classify the images as a whole. Amongst all these methods many reached good results with an accuracy far above 80%. In the future, approaches and ideas which are proven to work well from methods which were already proposed can be extracted, combined and further improved. Especially a combination of deep learning and precise feature extraction, like Ouchtati et Al. did in their approach, sounds promising. New approaches might yield results which can be trustworthy enough such that the approaches are actually applied in real life.

REFERENCES

[1] National Cancer Institute, https://seer.cancer.gov/statfacts/html/brain.html

[2] F. Ali-Osman, ”Contemporary Cancer Research, Brain Tumors”, Humana Press 2005

[3] N. Nandha Gopal, Dr. M. Karnan, “Diadnose Brain Tumor Through MRI Using Image Processing Clustering Algorithms Such As Fuzzy C means Along With Intelligent Optimization Techniques”, IEEE, 2010.

[4] A. R. A. Abdulraqeb, W. A. Al-haidri and L. T. Sushkova, ”A novel segmentation algorithm for MRI brain tumor images,” 2018 Ural Symposium on Biomedical Engineering, Radioelectronics and Information Technology (USBEREIT), Yekaterinburg, 2018, pp. 1-4.

[5] A. Min and Z. M. Kyu, ”MRI Images Enhancement and Tumor Segmentation for Brain,” 2017 18th International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT), Taipei, 2017, pp. 270-275. doi: 10.1109/PDCAT.2017.00051

[6] N. Kaur and M. Sharma, ”Brain tumor detection using self-adaptive K-means clustering,” 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai, 2017, pp. 1861-1865.

[7] N. Boughattas, M. Berar, K. Hamrouni and S. Ruan, ”Feature selection and classification using multiple kernel learning for brain tumor segmen-tation,” 2018 4th International Conference on Advanced Technologies for Signal and Image Processing (ATSIP), Sousse, 2018, pp. 1-5.

[8] Nilesh Bhaskarrao Bahadure, Arun Kumar Ray, Har Pal Thethi, “Image Analysis for MRI Based Brain Tumor Detection and Feature Extraction Using Biologically Inspired BWT and SVM, Hindawi, 06.03.2017

[9] M.Monica Subashini, Sarat Kumar Sahoo, Venika Sunil, Sudha Easwaran, “A Non-invasive methodology for the grade identification of astrocytoma using image processing and artifical intelligence techniques”, Expert System with Applications Elsevier Journal, vol.43, pp.186-196,2016.

[10] T. Chithambaram and K. Perumal, ”Brain tumor segmentation using genetic algorithm and ANN techniques,” 2017 IEEE International Con-ference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), Chennai, 2017, pp. 970-982.

[11] A. S. Parihar, ”A study on brain tumor segmentation using convolution neural network,” 2017 International Conference on Inventive Computing and Informatics (ICICI), Coimbatore, 2017, pp. 198-201

[12] A. Hazra, A. Dey, S. K. Gupta and M. A. Ansari, ”Brain tumor detection based on segmentation using MATLAB,” 2017 International Confer-ence on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai, 2017, pp. 425-430.

[13] V. Dhanve and M. Kumar, ”Detection of brain tumor using k-means segmentation based on object labeling algorithm,” 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), Chennai, 2017, pp. 944-951.

[14] Nitish Zulpe, Vrushsen Pawar, “GLCM Textural Features for Brain Tumor Classification”, International Journal of Computer Science Issues, vol.9,Issue 3, no.3,pp.354-359,May 2012.

[15] Jothi G, Hannah Inbarani H, “Hybrid Tolerance Rough Set-Firefly based supervised feature selection for MRI brain Tumor Image Classification”, Applied Soft Computing Elsevier Journal, no.46,pp. 639-651,2016.

[16] Ch.Amulya, G.Prathibha, “ MRI Brain Tumor Classification Using SURF and SIFT Features”, International Journal for Modern Trends in Science and Technology,vol.2, Issue.7,ISSN:2455-3778,pp.123-127,July 2016.

[17] Ankit Vidyarthi, Namita Mittal, “Performance Analysis of Gabor-Wavelet based Features in Classification of High Grade Malignant Brain Tumors”, IEEE 39th National System Conference, Dec 2015.

[18] Sonali B Gaikwad, madhuri S Joshi, “Brain Tumor Classification Us-ing Principal Component Analysis and Probabilistic Neural Network”, International Journal for Computer Applications, Vol-120, no:3,pp.5-9, June 2015.

[19] Qurat-ul Ain, Irfan Mehmood, M. Naqi Syed, M Arfan Jaffar, “Bayesian Classification Using DCT Features for Brain Tumor Detection”, Lectrure notes in Computer Science, Vol:6276, pp:340-349, 2010.

[20] E.F.Badran, E.G. Mahmoud, N.Hamday, “An Algorithm for Detecting Brain Tumors in MRI images”, Proceedings of the International Conference on Computer Engineering and Systems(ICCES),Cairo,pp:368-373,2010.

[21] Sneha Khare, Neelesh Gupta, Vibhanshu Srivastava, “Optimization Technique, Curve Fitting and Machine Learning used to Detect Brain Tumor in MRI”, ICCCS, 20-21 Feb 2014.

[22] K.B.Vaishnavee, K.Amshakala, “An automated MRI Brain Image Segmentation and Tumor Detection using SOM-Clustering and Proximal Support Vector Machine Classifier”, ICETECH, 20 March 2015.

[23] Sudha B, Gopikannan P, Shenbagarajan A and Balasubramanian C, “Classification of Brain Tumor Grades using Neural Network”, proceedings of the world Congress on engineering, Lomdon, UK. Vol 1, pp.567-571,1998.

[24] Gladis Pushpa Rathi V P and Palani S, “ Brain Tumor MRI Image Classification with Feature Selection and Extraction using Linear Discriminant Analysis”, International Journal of Information Science and Techniques, vol.2, no.4, pp,131-146,2012.

[25] Dipali M Joshi, Rana N K and Misra V M, “ Classification of Brain Cancer Using Artifical Neural Network”, IEEE Conference on Electronic Computer Technology, ICECT,pp.112-116,2010.

[26] Ahmed Kharrat, Karim gasmi, Mohamed Ben Messaoud, Nacra Be-namrane and Mohamed Abid, “A Hybrid Approach for Automatic Classification of brain MRI using Genetic Algorithm and Support Vector Machine”, Lenardo Journal of Sciences, vol.17,pp.71-82,2010.

[27] S. Chauhan, A. More, R. Uikey, P. Malviya and A. Moghe, ”Brain tumor detection and classification in MRI images using image and data mining,” 2017 International Conference on Recent Innovations in Signal processing and Embedded Systems (RISE), Bhopal, 2017, pp. 223-231.

[28] S. Ouchtati, J. Sequeira, B. Aissa, R. Djemili and M. Lashab, ”Brain tumors classification from MR images using a neural network and the central moments,” 2018 International Conference on Advanced Systems and Electric Technologies (ICASET), Hammamet, 2018, pp. 455-460.

[29] F. P. Polly, S. K. Shil, M. A. Hossain, A. Ayman and Y. M. Jang, ”Detection and classification of HGG and LGG brain tumor using machine learning,” 2018 International Conference on Information Networking (ICOIN), Chiang Mai, 2018, pp. 813-817.