# A Review on Mathematical Morphology to Detect Brain Tumor using Magnetic Resonance Imaging in Image Segmentation

**Alok Kumar Choudhary[1], Ashish Dubey [2]**
[1]Dept of Electronic Communication
[2]Asst. Professor , Dept of Electronic Communication
[1, 2] ShriRam College of Engineering & Management, Banmore, Gwalior-476444, M.P. , India

***Abstract-*** *Image segmentation is a procedure, which split a picture, which are comparative in some viewpoint and change over it into paired frame for preparing. Brain tumor is a growth of abnormal tissues inside the brain. It causes pressure in skull region and affects the normal functioning of brain. Brain tumors are classified as benign and malignant tumors. Magnetic resonance imaging (MRI) is high-quality medical imaging, particularly for brain imaging . MRI inside the human body is helpful to see the level of detail. Mathematical Morphology potential lies in the fact of quantifying the intuition of the researcher, analyzing the geometric structure of images from a perfectly defined and known structuring element set. Mathematical morphology constitutes a well defined framework for non-linear image processing based on set relations.In this survey we discuss various image segmentation techniques, MM application, role, as well as MRI or Brain tumor detection.*

***Keywords***- Image segmentation, Brain tumor, Magnetic resonance imaging (MRI), Mathematical morphology.

## I. INTRODUCTION

Image processing is any form of signal processing in which the input will be given as an image, such as a photograph or video frame; the output of image processing will be either an image or a set of characteristics or parameters that are related to given image. Image processing involves processing or altering an existing image in a desired manner and also helps in obtaining the image in the readable format. Most techniques of image-processing involve treating the image as 2 -dimensional signal and applying standard signal-processing techniques to it. Image processing is a technique to translate an image into digital form and execute some operation on it, in order to get an improved image or to retrieve useful data from image. It is a procedure of signal distribution. The process takes input as an image and then apply efficient algorithms, and the results may be image, data or features associated with that image. The processing stages start with image segmentation.

Image segmentation is a procedure, which split a picture, which are comparative in some viewpoint and change over it into paired frame for preparing. Segmentation process is the primary step in many image processing. Procedure incorporates object characteristic and portrayal and detail estimation. Higher request errand takes after the grouping of object. Hence, classification, imagining of region of interest in any image, description plays a substantial role in image segmentation. There are numerous segmentation algorithms available in the literature, which split an image into number of regions based on some picture attributes like pixel quality esteem, shading, color, shape etc. Segmentation method split the region using different method such as single or multiple thresh holding, segmentation on parallel region, segmentation using clustering, edge detection, and also segmentation on fuzzy logic technique etc [2].

Brain tumor is a growth of abnormal tissues inside the brain. It causes pressure in skull region and affects the normal functioning of brain. Brain tumors are classified as benign and malignant tumors. Benign tumors are non cancerous. Malignant tumors are cancerous tumors in which brain tissues split endlessly and can spread into surrounding tissues. Identification and classification of brain tumors into benign or malignant type is important for further treatment and survival of patients. Different medical image modalities like Computer Tomography(CT), Poisson Emission Tomography(PET), Magnetic Resonance Images (MRI) are used for brain tumor detection. [3].

Magnetic resonance imaging (MRI) is high-quality medical imaging, particularly for brain imaging. MRI inside the human body is helpful to see the level of detail. Doctors have major technical and economic importance of reliable and fast detection and classification of brain cancer, based on common practices. Most of the technicians are slow, less responsible, and that's hard to quantify possess a degree of subjectivity. Detection of brain tumor from MRI images involves various Phases such as Preprocessing, Feature extraction, Segmentation and classification. MRI Image

segmentation is based on set of process of brain tumor detection; pixel intensity based features are extracted. Image Segmentation group pixels into regions and hence defines the object regions. Segmentation uses the features extracted from image. Classification is the last step in process of brain tumor image into normal or abnormal and classifies the abnormality type whether it is benign or malignant. This study evaluates various techniques which are used in tumor detection from brain MRI [4].

Mathematical Morphology is developed from set theory. Morphology was originally developed for binary images, and was shortly extended to grayscale functions and images. Morphology is a broad set of image processing, process that process images supported on shapes . Morphology is most commonly applied to digital images, but it can be employed as well on graphs, meshes, solids, and many other spatial structures. Mathematical morphology is a way of nonlinear filters, which could be used for image processing as well as noise suppression, feature extraction, edge detection, image segmentation, shape recognition, texture analysis, image restoration and reconstruction, image compression etc. Mathematical morphology provides an approach to the processing of digital images which is based on shapes [5].

## II. IMAGE SEGMENTATION

Image segmentation is early or front stage processing of image compression. The efficiency of the segmentation process is its speed, good shape matching and best shape connectivity with it is segmenting result. The Segmentation refers to the process of identifying and isolating the surface and regions of the digital image which corresponds to the structural units. Segmentation may moreover depend on various features that are contained in the image it may be either color or texture. Image Segmentation is one of the emerging trends in the field of image processing. It has found applications in the field of satellite imagery, medical applications etc. Image segmentation is the basic step to analyze images and extract data from them. Along with the various image processing techniques in the image, segmentation is edge detection, Thresholding, region growing, and clustering is used to segment the images [6].

### A. CLASSIFICATION OF SEGMENTATION TECHNIQUES

#### 1. Segmentation by Edge Detection

Edge detection method is a basic step of image segmentation process. The image divides into the object and its background. Divides the image on edge detection method by observing the change in intensity or pixels of an image. Divided into two categories edge detection operators as first-order derivative operators and second order derivative operators .The canny edge detector is a second order derivative operator. The Second-order derivative operators to give reliable results.

#### 2. Segmentation By Thresholding

Image segmentation is segmented image One of the simplest approaches to the image is based on the intensity levels and is called as threshold based. Thresholding can be implemented either globally or locally. Global thresholding distinguishes object and background pixels by comparing with threshold value chosen and use a binary partition to segment the image. Local thresholding technique is also called adaptive thresholding. Adaptive thresholding technique, are threshold value varies the image depending on the local characteristic of the sub separated regions in the image.

#### 3. Segmentation by Region based

In this technique pixels that are associated with same object are sorted for segmentation. The thresholding technique is sure with region primarily based segmentation. The area that's detected for segmentation ought to be closed. Region primarily based segmentation is additionally termed as Similarity primarily based Segmentation. There won't be any gap thanks to missing edge pixels during this region primarily based segmentation the boundaries are known for segmentation.

#### 4. Segmentation by Feature

Based Clustering: Clustering a method of organizing the team supported its attributes. A cluster usually contains a group of similar pixels that belongs to a specific region and completely from other regions. The term information clump as synonyms like cluster analysis, automatic classification, numerical taxonomy, botrology and typological analysis. Images can be grouped based on its content. The clump ways are sometimes divided as hierarchical algorithms and partition algorithms. In content based mostly clump, grouping is finished betting on the genetic characteristics of the pixels like form, texture etc. There are numerous clump techniques used, the foremost wide used are K-means algorithmic rule and fuzzy C-means algorithmic rule.

#### 5. Segmenting By K Means Clustering

The fourth segmentation technique employed in this work is k suggests that clump algorithmic program. Images

can be grouped based on its content. The bunch strategies ar sometimes divided as gradable algorithms and partitional algorithms. In content primarily based bunch, grouping is done depending on the inherited characteristics of the pixels like shape, texture etc. There are varied bunch techniques utilized, the foremost wide used ar K-means algorithmic program and fuzzy C-means algorithmic programre generate to double values. Using this, row and column values are obtained. Then the amount of clusters to be created is appointed to 5. Resizing and displaying are done in image values.

### 6. PDE Based Image Segmentation

PDE (Partial Differential Equations) equations or PDE models are used widely in image processing, and specifically in image segmentation. They uses active contour model for segmentation purpose .Active Contour model or Snakes transform the segmentation problem into PDE .Some famous methods of PDE used for image segmentation are Snakes ,Level Set, and Mumfordshah method.

### 7. ANN Based Image Segmentation

Artificial Neural Network, every neuron is corresponding to the pixel of an image .Image is mapped to the neural network. Image in the form of neural network is trained using training samples, and then connection between neurons, i.e., pixels is found. Then new images are segmented from the trained image. Some of the mostly used neural networks for image segmentation are Hopfield ,BPNN,FFNN,MLFF,MLP, SOM, and PCNN. Segmentation of image using neural network is performed in two steps, i.e. ,pixel classification and edge detection. In this section several new approaches of ANN used for image segmentation is discussed from last five years.

### 8. Fuzzy Theory Based Image Segmentation

Fuzzy set theory is used in order to analyze images, and provide accurate information from any image. Fuzzification function can be used to remove noise from image as well. Agray-scale image can be easily transformed into a fuzzy image by using a fuzzification function. Different morphological operations can be combined with fuzzy method to get better results. Fuzzy k-Means and FuzzyC-means (FCM)are widely used methods in image processing [7].

## III. BRAIN TUMOR

Brain is the center of human central nervous system. The brain is a complex organ as it contains 50-100 billions neurons forming a gigantic network. A brain tumor is a mass of unnecessary and abnormal cell growing in the brain or it can be defined as an intracranial lesion which occupies space within the skull and tends to cause a rise in intracranial pressure. Brain tumors are mainly classified into two i.e. Benign and Malignant. Benign tumors are noncancerous and they seldom grows back where as malignant tumors are cancerous and they rapidly grows and invade to the surrounding healthy brain tissue. [8].

There are two types of tumor that can develop in brain; primary tumor and secondary tumor. The primary tumor in brain is classified as low grade or high grade. A low-grade tumor mostly grows very slowly; but with the pace of time, it can turn out to be of a high-grade tumor. High-grade tumor grows very rapidly and hits the brain. In adults, secondary brain tumors which are also called brain metastases, occurs more frequently in adults than the primary tumors.

### 1. Types of primary brain tumor

#### a. Benign Tumor

This type of tumor is not taken as cancer. It grows very slowly (Ridhi, Salankar, & Babar, 2015) [1]. This type of brain tumors usually grows in isolated tissues so generally these are not dangerous, as once they are removed, tumor cells are finished so they don't emerges back in the brain. A benign tumor can give rise to symptoms like a malignant tumor depending where the tumor is located according to size and location.

#### b. Malignant tumor

This type of tumor is treated as a cancer. In this tumor, cells grows very rapidly, and harm near by tissue which is very difficult to remove partially they are operated. A malignant brain tumor may grow back after treatment.

### 2. Types of brain tumors

There are nearly hundred types of brain tumors which include

- Gliomas
- Astrocytoma
- Pilocytic Astrocytoma (grade I)
- Diffuse Astrocytoma (grade II)
- Anaplastic Astrocytoma (grade III)
- Glioblastoma Multiforme (grade IV)
- Oligodendroglioma (grade II)
- Anaplastic Oligodendroglioma (grade III)

- Ependymoma (grade II)
- Anaplastic Ependymoma (grade III) [9].

## IV. MAGNETIC RESONANCE IMAGING (MRI)

MRI is commonly used in the medical field for detection and visualization of details in the internal structure of the body. It is basically used to detect the differences in the body tissues which have a considerably better technique as compared to computed tomography. Thus, this technique become a special technique especially for the brain tumor detection and cancer imaging. Basically, for comparison, CT uses ionizing radiation while MRI uses strong magnetic field to align the nuclear magnetization that follows by changes the alignment of the magnetization by radio frequencies that can be detected by the scanner. The signal produced can be further processed later to gain extra information of the body [10].

MRI images are usually used in brain scans, because such photos show brain tumours for good quality pictures. Tumors of the brain. MRI offers interactive tissue capacity in any tissue aircraft. Images generated by MRI Scanner are divided into vertically and horizontally stages in total value introduced. Such MRI analysed pictures are useful in recognising and describing tumour elements of the brain. Most of the approaches nowadays are an analysis of human behavior for picture recognition that may contribute to the misidentification of brain tumors. As compared to the manual, the digital way to view images that render us aware. Data is obtained from complicated diagnostic photographs utilizing the Segmentation methodology. The primary purpose is to split the picture into separate image classification partitions, but risk variables will only be considered. The main method for detection & control of brain tumors in magnetic resonance imaging. Specific patient MRI modalities are acquired and analyzed using computer-based image processing techniques to cope with the difficulty and time and objectivity constraints.[11]

## V. MATHEMATICAL MORPHOLOGY

Mathematical morphology constitutes a well defined framework for non-linear image processing based on set relations. It relies on minimum and maximum values over neighborhoods (i.e. regions surrounding the individual points) defined by shapes or functions known as structuring elements. Classical morphological operations use a predefined structuring element which is used repeatedly for each point in the image. This is often not ideal, however, which has motivated the evolution of adaptive morphological filtering where the structuring element changes from point to point. The field of adaptive mathematical morphology includes many different concepts with different strengths and weaknesses, and the specific choice of method should be made with the specific application in mind [12].

### A. ROLE OF MATHEMATICAL MORPHOLOGY

#### 1. Image Enhancement

Improving pictures ultimately increases interpretability or interpretation of details for human viewers in pictures & offers 'better' feedback for other digital IP technology. top-of-top transformers and bot-hats transform recover contrast of images[5]. the effect is then used for the iterative threshold section closing and opening operations.

#### 2. Text Extraction for Image

The image text provides helpful material to get the general meaning behind the photo. In several applications, image extraction is critical. Extraction of text knowledge contained in pictures from situations shows numerous applications, such as automated classification, indexing, picture structuring, record analysis, extraction of automobile licenses tag, professional paper analysis and encoding of object-oriented details. Edge identification is achieved using mathematical morphology.

#### 3. Image compression

Image compression is the digital picture output, with a few bits as necessary though retaining an appropriate image quality For image compression mathematical morphological operations can be required. To define or construct clusters of essential coefficients, a significance chart is preprocessed with mathematical morphology operators. The usage of the self-organizing mathematical morphology feature-map-based imaging method in large picture classes contributed to a good PSNR compression ratio.

#### 4. Noise Detection

This is an implementation of MM in IP, which helps one to find and even remove noise in the binary picture by utilizing this method. The geometry arrangement of a picture underlines morphological image processing. How does the structuring item detect an image? Specific operations are used here to extend, erode, open and close mathematical morphology. The best way to delete unnecessary information from an initial picture is byutilizing degradation (in terms of the size).

#### 5. Component Analysis

This is a new phenomenon, that recognizes handwriting and allows the handwritten numbers to be recognized utilizing mathematical morphology with various operators/structural element. The man's computer interface can be used as this method, and this definition helps you to use software directly with handwriting, despite typing. Handwritten physical identification can be divided into two categories: offline and web.

**6. License Plate Recognition System**

The license plate number can be identified automatically through mathematical morphology in this system[8]. First, the device is used to capture the snapshot of the license plate, and then the pictures are loaded on the screen via video cards [13].

**B. APPLICATIONS OF MM**

a. Fingerprint Feature Extraction
b. Recognition of Handwritten Digits
c. License Plate Detection
d. Border Extraction
e. Denoising using Morphological Filters
f. Text Extraction
g. Detection of Imperfection in Printed Circuit Boards [14]

## VI. LITERATURE REVIEW

**Lather, M., & Singh, P. (2020)** Brain tumor is a life-threatening problem and hampers the normal functioning of the human body. For proper diagnosis and efficient treatment planning, it is necessary to detect the brain tumor in early stages. Digital image processing plays a vital role in analysis of medical images. Segmentation of brain tumor involves separation of abnormal brain tissues from normal tissues of brain. In the past, various researchers have proposed the semi and fully automatic methods for detection and segmentation of brain tumor. In this article, the different techniques available for segmentation have been presented. This article focuses on the work done by many researchers in the past to partially or fully automate the job of segmenting the brain tumor. The consolidated details of the reviewed literature have been tabulated. Simplicity and degree of human supervision decides the clinical acceptance of a particular segmentation technique [15].

**Zhou, Z., He, Z., & Jia, Y. (2020)** with a single stride to replace pooling/striding and build the backbone for feature learning. For the second problem, a 3D atrous-convolution feature pyramid is designed and added to the end of the backbone. By integrating with contextual features, this structure improves the discriminating ability of the overall model to segment tumors with various sizes. Finally, a 3D fully connected Conditional Random Field is constructed as a post-processing step for the network's output to obtain structural segmentation of both the appearance and spatial consistency. Abundant ablation experiments carried on Magnetic Resonance Imaging datasets demonstrate that lossless feature computation and multi-scale information fusion driven by our method are feasible to address the above problems. Compared with the state-of-the-art methods on the public benchmarks, our method achieves competitive performance and can be efficiently implemented into the clinical medical application [16].

**Arti Tiwari et al. [2019]** Past few years have witnessed a significant increase in medical cases related to brain tumor, making it the 10th most common form of tumor affecting children and adults alike. However, it also one of the most curable form of tumors if detected well on time. Consequently scientists and researchers have been working towards developing sophisticated techniques and methods for identifying the form and stage of tumor. Magnetic Resonance Imaging (MRI) widely used for resectioning and examining the abnormalities in terms of shape, size or location of brain tissues which in turn help in detecting the tumors. The way toward sectioning tumor from MRI picture of a brain cerebrum is one of the profoundly engaged regions in the network of medical science as MRI is non-invasive imaging. This paper provides a systematic literature survey of techniques for brain tumor segmentation and classification of abnormality and normality from MRI images based on different methods including deep learning techniques, metaheuristic techniques and hybridization of these two. It incorporates the presentation and quantitative investigation from the conventional segmentation and classification techniques to of best in class strategies [17]

**Wadhwa, A., et al. [2019]** This paper discusses a thorough literature review of recent methods of brain tumor segmentation from brain MRI images. It includes the performance and quantitative analysis of state-of-the-art methods. Different methods of image segmentation are briefly explained with the recent contribution of various researchers. Here, an effort is made to open new dimensions for readers to explore the concerned area of research. Through the entire review process, it has been observed that the combination of Conditional Random Field (CRF) with Fully Convolutional Neural Network (FCNN) and CRF with DeepMedic or Ensemble are more effective for the segmentation of tumor from the brain MRI images [18].

**Sumathi, R., et al. [2018]** This article presents an unique algorithm which is developed based on Kapur's Entropy-based Cuckoo Search Optimization and Morphological Reconstruction Filters. The former is used to locate and segment the boundary of tumors, while the later to remove unwanted pixels in the slice images. The proposed method yields 97% accuracy in the identification of the exact topographical location of tumor region. It requires less computational time (about 3 milliseconds, on average) for processing. Thus the proposed method can help radiologists quickly detect the exact topographical location of tumor regions even when there are severe intensity variations and poor boundaries. The method fares well in terms also of other standard comparison metrics like entropy, eccentricity, Jaccard Index, Hausdorff distance, MSE, PSNR, precision, recall and accuracy, when compared to the existing methods including Fuzzy C Means clustering and PSO. Above all, the algorithm developed can detect the tumor regions in the MR images of both brain and breast. The method is validated using various types of MR images (T1, T2 for MRI brain, and T1 post contrast and post processed images for breast) available in the online datasets of BRATS, RIDER and Harvard [19].

**Narayanan, A., et al. [2018]** The impact of cancer cells is irretrievable and it has paved the way to the formation of tumors within the human body. For achieving and developing a single-structured framework to prominently identify the tumor regions and segmenting the tissue structures specifically in human brain, a novel combinational algorithm is proposed through this paper. The algorithm has been embodied with two optimization techniques namely particle swarm optimization (PSO) and bacteria foraging optimization (BFO), wherein, PSO helps in finding the best position of global bacterium for BFO, consecutively, BFO supports the modified fuzzy c means (MFCM) algorithm by providing optimized cluster heads. Finally, MFCM segments the tissue regions and identifies the tumor portion, thereby reducing the interaction and complication experienced by a radiologist during patient diagnosis. The strength of the proposed algorithm is proven by comparing it with the state-of-the-art techniques by means of evaluation parameters like mean squared error (MSE), peak signal to noise ratio (PSNR), sensitivity, specificity, etc., Data sets used in this paper were exclusively obtained from hospital, Brain web simulator and BRATS-2013 challenge [20]

**Devkota, B., et al. [2018]** this study proposes a computer aided detection approach to diagnose brain tumor in its early stage using Mathematical Morphological Reconstruction (MMR). Image is pre-processed to remove noise and artefacts and then segmented to find regions of interest with probable tumor. A large number of textural and statistical features are extracted from the segmented image to classify whether the brain tumor in the image is benign or malignant. Experimental results show that the segmented images have a high accuracy while substantially reducing the computation time. The study shows that the proposed solution can be used to diagnose brain tumor in patients with a high success rate [21].

## VII. CONCLUSION

Image segmentation is a procedure, which split a picture, which are comparative in some viewpoint and change over it into paired frame for preparing. Segmentation process is the primary step in many image processing. Procedure incorporates object characteristic and portrayal and detail estimation. A brain tumor is a mass of unnecessary and abnormal cell growing in the brain or it can be defined as an intracranial lesion which occupies space within the skull and tends to cause a rise in intracranial pressure. MRI Image segmentation is based on set of process of brain tumor detection; pixel intensity based features are extracted. Image Segmentation group pixels into regions and hence defines the object regions. Segmentation uses the features extracted from image. Morphology is most commonly applied to digital images, but it can be employed as well on graphs, meshes, solids, and many other spatial structures. Mathematical morphology is a way of nonlinear filters, which could be used for image processing as well as noise suppression, feature extraction, edge detection, image segmentation, shape recognition, texture analysis, image restoration and reconstruction, image compression etc

## REFERENCES

[1] A. Jain, Fundamentals of Digital Image Processing, Prentice Hall International, Englewood Cliffs, 1989.

[2] Sahil V. Khedaskar," A Survey of Image Processing and Identification Techniques", VIVA-Tech International Journal for Research and Innovation, Volume 1, Issue 1 (2018), ISSN(Online): 2581-7280, PP 1-10

[3] Dhanashri Joshi, Hemlata Channe," A Survey On Brain Tumor Detection Based On Structural MRI Using Machine Learning And Deep Learning Techniques.", INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 9, ISSUE 04, APRIL 2020 ISSN 2277-8616

[4] Shanti Parmar," A Survey on Detection and Classification of Brain Tumor from MRI Brain Images using Image Processing Techniques", International Research Journal of Engineering and Technology (IRJET) ,e-ISSN: 2395-0056, Volume: 05 Issue: 02 | Feb-2018

[5] N.Senthilkumaran et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5 (3) , 2014, 2684-2688

[6] C.Mariyamma," Survey on Image Segmentation Methods", International Advanced Research Journal in Science, Engineering and Technology, Vol. 5, Issue 11, November 2018, ISSN (Online) 2393-8021

[7] G.Ramya and 2A.S Shanthi," Segmentation Techniques for Image Analysis – A Survey", International Journal of Trend in Research and Development, Volume 2(6), ISSN 2394-9333

[8] Kalifa Shantta," Brain Tumor Detection and Segmentation: A Survey", IRA-International Journal of Technology & Engineering, ISSN 2455-4480; Vol.10, Issue 04 Pg. no. 55-61

[9] Damandeep Kaur, Surender Singh," Detection of Brain Tumor using Image Processing Techniques", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958, Volume-8, Issue-5S3, July 2019

[10] Ed-Edily Mohd. Azhari," TUMOR DETECTION IN MEDICAL IMAGING: A SURVEY", International Journal of Advanced Information Technology (IJAIT) Vol. 4, No. 1, February 2014

[11] HarshiniBadisa," CNN Based Brain Tumor Detection", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-8 Issue-4, April 2019

[12] diva-portal.org/smash/get/diva2:991343/FULLTEXT01.pdf

[13] Pratishtha Gupta," A SURVEY OF TECHNIQUES AND APPLICATIONS FOR REAL-TIME IMAGE PROCESSING", Volume 4, No. 8, August 2013 Journal of Global Research in Computer Science REVIEW ARTICLE Available Online at www.jgrcs.info

[14] Beant Kaur," Applications of Mathematical Morphology in Image Processing: A Review", 1,2Dept. of ECE, University College of Engineering, Punjabi University, Patiala, Punjab, India, IJECT Vol. 4, Issue Spl - 3, April - June 2013, ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print)

[15] Lather, M., & Singh, P. (2020). Investigating Brain Tumor Segmentation and Detection Techniques. Procedia Computer Science, 167, 121–130. doi:10.1016/j.procs.2020.03.189

[16] Zhou, Z., He, Z., & Jia, Y. (2020). AFPNet: A 3D Fully Convolutional Neural Network with Atrous-convolution Feature Pyramid for Brain Tumor Segmentation via MRI Images. Neurocomputing. doi:10.1016/j.neucom.2020.03.097

[17] Arti Tiwari , Shilpa Srivastava , Millie Pant , Brain Tumor Segmentation and Classification from Magnetic Resonance Images: Review of selected methods from 2014 to 2019, Pattern Recognition Letters (2019), doi: https://doi.org/10.1016/j.patrec.2019.11.020

[18] Wadhwa, A., Bhardwaj, A., & Singh Verma, V. (2019). A review on brain tumor segmentation of MRI images. Magnetic Resonance Imaging, 61, 247–259. doi:10.1016/j.mri.2019.05.043

[19] Sumathi, R., Venkatesuslu, M., & Arjunan, S. P. (2018). Extracting tumor in MR brain and breast image with Kapur's entropy based Cuckoo Search Optimization and morphological reconstruction filters. Biocybernetics and Biomedical Engineering. doi:10.1016/j.bbe.2018.07.005

[20] Narayanan, A., Rajasekaran, M. P., Zhang, Y., Govindaraj, V., & Thiyagarajan, A. (2018). Multi-channeled MR brain image segmentation: A novel double optimization approach combined with clustering technique for tumor identification and tissue segmentation. Biocybernetics and Biomedical Engineering. doi:10.1016/j.bbe.2018.12.003

[21] Devkota, B., Alsadoon, A., Prasad, P. W. C., Singh, A. K., & Elchouemi, A. (2018). Image Segmentation for Early Stage Brain Tumor Detection using Mathematical Morphological Reconstruction. Procedia Computer Science, 125, 115–123. doi:10.1016/j.procs.2017.12.017