Brain Tumor Detection and Segmentation using Hybrid Approach of MRI, DWT and K-means

Parvinder Singh[1], Mansi Lather[2]
[1, 2] Department of Computer Science and Engineering
[1,2] Deenbandhu Chhotu Ram University of Science and Technology, Murthal, Sonepat, India
[1] parvindersingh.cse@dcrustm.org
[2] lathermansi@gmail.com

Abstract— **In medical image processing, the detection of a brain tumor is considered as one of the most difficult and time consuming activities. The foremost aim of this paper is to design an efficient algorithm for brain tumor detection and segmentation. This paper presents an improved hybrid method using Discrete Wavelet Transform (DWT), morphological operators, K-means and Otsu's thresholding technique for detecting and segmenting the tumor in the brain. DWT is used for image denoising. Morphological operators are used for removing the skull portions from the brain images and K-means clustering and thresholding approaches are used for image segmentation and finally to detect the brain tumor. The proposed method results in low values of Mean Square Error (MSE) and Bit Error Rate (BER) and high value of Peak Signal to Noise Ratio (PSNR) as compared to existing watershed and region growing segmentation methods and thus outperforms the existing methods.**

Keywords-Brain Tumor; Image Denoising; K- means Segmentation; Magnetic Resonance Imaging (MRI); Morphological Operators; Skull Removal.

I. INTRODUCTION

The brain is regarded as the command center of the nervous system, and it is the most complicated organ inside the human body. It is a non-replaceable, soft and spongy mass of tissue. The human brain takes inputs from the sensory organs and forwards them as outputs to the muscles [1]. Intelligence, creativity, emotions, memory, etc., are governed by the brain [2]. Therefore, any damage or harm in the brain will cause problems for personal health including mobility or cognition [1].

In diagnosing brain tumors, precise measurements are very difficult because of the diversity in size, shape and appearance of tumors. A brain tumor is an abnormal and uncontrolled propagation of cells [3]. A brain tumor does not only impact the immediate cells in its location, but it can also cause damage to surrounding cells by causing inflammation. In medical image processing, brain tumor detection is considered as one of the most difficult and time consuming activities [12]. Medical imaging techniques play an important role in tumor detection. Among the various medical imaging modalities, MRI is regarded as the most proficient means for analyzing the body's internal structure [5]. Timely and precise tumor detection is necessary for efficiently planning the treatment. In this paper, we develop a hybrid technique for brain tumor detection using DWT, morphological operators and K-means segmentation.

The important goal of the image processing application proposed here is to use the image data to abstract the required attributes which are then used by a machine to obtain an interpretative, descriptive, or reasonable diagnosis.

Among the various image processing steps, in case of brain tumor detection, the main ones are image denoising, morphological operation and image segmentation.

Image denoising is defined as the method of removing noise from the image. In medical imaging, for easy and proper diagnosis of diseases, denoising produces a clearer image [5]. Various schemes are available for removing noise from images [4][14]. The selected diagnostic method should be capable of retrieving as much detail as possible from the image regardless of any high degradation of the image by noise. The image denoising methods are broadly categorized as [4]:

- **Spatial filtering methods**
  Include linear and non-linear filters.
- **Transform domain filtering methods**
  Include spatial frequency filtering methods and wavelet domain methods.

Morphological operators are non-linear operators dealing with morphology and shape of images. They are related to pixel ordering and they do not change the pixel's numerical value. These operators use a small matrix of pixels called structuring element in which each pixel has value one or zero and the choice of suitable structuring element plays an important role in the process. Various types of morphological operators include erosion, dilation, opening and closing [5].

Image segmentation is the process of using automatic or semi-automatic means of extracting the region of interest from an image [9]. Segmentation techniques used for analyzing medical images are classified as [6]:

- **Region based methods**
  Include thresholding and region growing methods.
- **Classification methods**
  Include k-nearest neighbor and maximum likelihood methods.

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- **Clustering methods**
  Include K-means, Fuzzy C-Means (FCM) and expectation maximization methods.

In this paper, we propose a new hybrid method using DWT, morphological operators, K-means and Otsu's thresholding technique for detecting and segmenting the tumor in the brain. Image denoising is done using DWT; The skull portion of the brain images is removed using morphological operators and image segmentation and final brain tumor detection is done using K-means clustering and thresholding.

This research paper is divided in five parts: in Section II, we present related literature works; in Section III, the proposed methodology is explained in detail; Section IV includes performance analysis and Section V concludes the paper.

II. LITERATURE REVIEW

In [5], *Ramya and Sasirekha* proposed a segmentation technique consisting of three phases: (1) a fourth order partial differential equation is used to denoise the image; then, (2) the morphological operators are used to remove the skull part and, finally, (3) segmentation is done using region growing segmentation. The precision of this method is higher than the watershed segmentation algorithm [5].

In [7], *Ayed, Halima and Kharrat* proposed an approach that consists of five stages: In the first stage, features are extracted using 2D Discrete Wavelet Transform and Spatial Gray Level Dependence Matrix (DWT-SGLDM). In the second stage, to reduce features size, features are selected using Simulated Annealing (SA). In the next stage, over fitting is avoided using Stratified K-fold Cross Validation. In the fourth stage, to optimize Support Vector Machine (SVM) parameters, Genetic Algorithm-SVM (GA-SVM) model is used. Finally SVM is used for creating the classifier.

In [8], *El-Khamy, El-Khoreby and Sadek* presented a hybrid approach of FCM and Conformed threshold. The proposed technique is composed of five steps: The first step involves enhancement of the intensity of input brain MR image using pre-processing for the next step. The second step involves the use of a rectangu1ar window for image histogram in order to ca1culate the number of c1usters for FCM input. The third step is to use FCM to find the center of clusters. The fourth step is to use the Conformed threshold value in order to segment the tumor. The final step uses segmented image to detect tumor. For correctness and processing time, this method gives better resu1ts than the globa1 thresho1d method of segmentation, but the completeness is better in globa1 thresho1d method as compared to their method.

In [10], *Gopal and Karnan* presented a hybrid approach such as FCM with GA and Particle Swarm Optimization (PSO) for detecting the tumor. The tumor detection is done in two phases. The first phase involves pre-processing and enhancement using the tracking algorithm to eliminate film artifacts and median filter to eliminate the high frequency components. The second phase involves segmentation and c1assification using GA with FCM and PSO with FCM. PSO with FCM technique outperforms GA with FCM technique.

In [11], *Selkar and Thakare* presented watershed and thresholding algorithm that consists of three stages. Firstly, quality of the scanned image is enhanced by removing noise. Secondly, thresholding and watershed segmentation is applied to get a high intensity portion called tumor from the whole image. Finally, edge detection operator is applied for extracting the boundary and for finding the tumor size. The result shows efficient tumor detection by using thresholding algorithm rather than watershed algorithm and canny edge operator gives efficient boundary extraction results rather than Prewitt and Robert operator.

In [12], *Arivoli, Lakshmi and Vinupriyadharshini* proposed a system consisting of two main steps: preprocessing and segmentation. The preprocessing step involves three methods. The first method is noise removal using curvelet transform, next is artifact remova1 and last is sku1l remova1 using mathematical morphology. Segmentation is done using spatia1 FCM.

In [13], *Beham and Gurulakshmi* proposed a method consisting of three steps: The first step is image enhancement in which outer elliptical shaped object is eliminated. The second step is morphological processing, conducted for extracting the needed region. The final step is the segmentation using K-means clustering algorithm. This unsupervised method is efficient and less prone to error and can be carried out with lesser amount of data giving accurate output compared to supervised methods.

To overcome the deficiencies of existing techniques, we propose an improved technique which is efficient in denoising of images corrupted by Gaussian noise. Gaussian noise can be effectively removed by using the wavelet techniques because of the ability of the wavelet to capture the energy of the signal in few energy transform values [15]. Moreover, threshold selection is done using automated means which gets an optimized value for global thresholding.

III. PROPOSED SYSTEM

In this paper, we propose a new hybrid method using DWT, morphological operators, K-means and Otsu's thresholding technique for detecting and segmenting the tumor in the brain. DWT is used for image denoising. Morphological operators (erosion and dilation) are used for sku1l removal from the brain images. K-means clustering and thresholding approaches are used for image segmentation. This segmentation is finally used to detect the brain tumor. The flow graph shown in Figure 1 depicts the step by step procedure to be followed for detecting the tumor.

A. Image Acquisition

Images are acquired using non-invasive Magnetic resonance imaging (MRI) scan. The MRI scanner has a sliding table, which goes inside the circular apparatus during acquisition. A sample brain image using MRI scan is shown

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in Figure 2 a) and then converted into grayscale as shown in Figure 2 b).

B. *Image Denoising*

In the proposed method, noise removal is done using DWT filtering. The wavelets are the functions that deal with both the frequency and the temporal components. Denoising of the images using wavelet technique is very effective, when images are degraded by Gaussian noise. This is because of their ability to capture the signal energy in few energy transform values [15]. The enhanced image after removing noise using DWT filtering is shown in Figure 2 c).

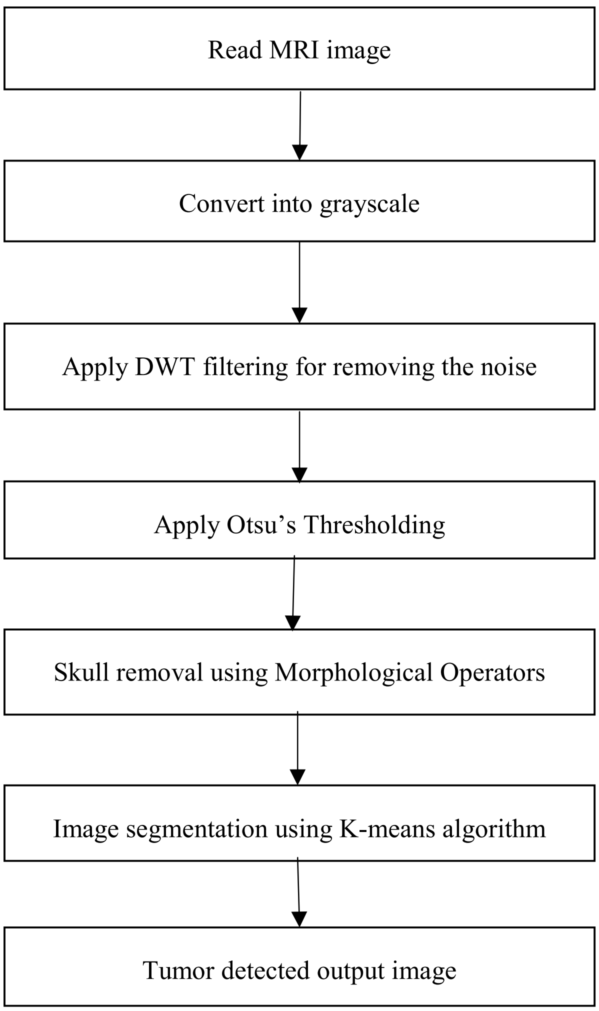

Figure 1. Proposed methodology for tumor detection.

C. *Otsu's Thresholding*

Otsu's thresholding is applied to the enhanced image after denoising using DWT filtering technique. The purpose of Otsu's thresholding method is to get an optimized value for g1obal thresholding. In Otsu's thresholding, it is pre-assumed that image has 2 c1asses of pixe1s or a bimoda1 histogram. The pixels in image are divided into two categories- foreground and background. The segmented image after applying Otsu's thresholding is shown in Figure 2 d).

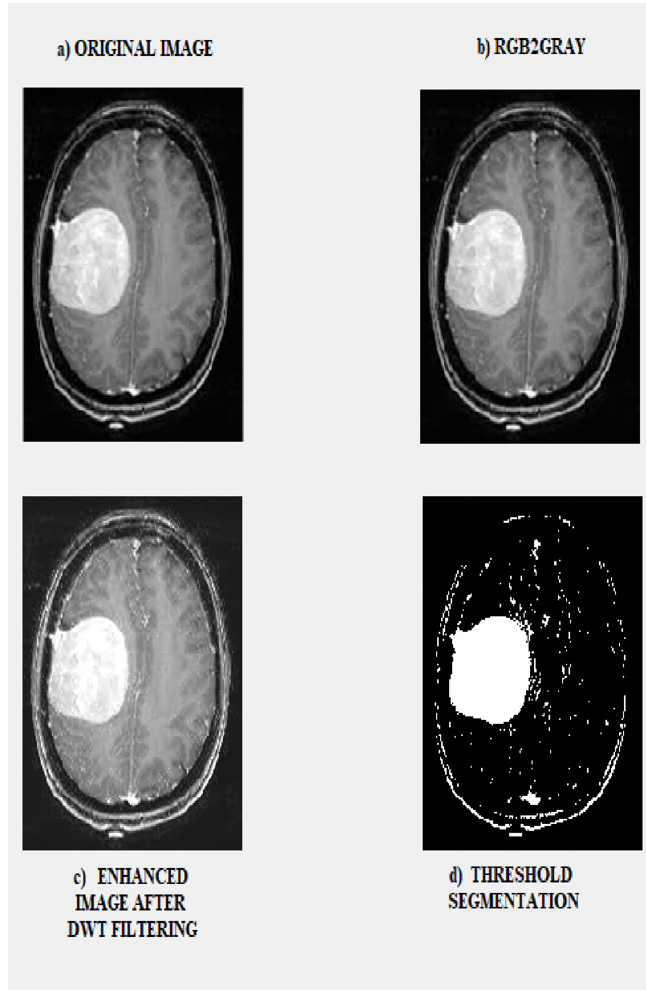

Figure 2. a) Input brain MRI image; b) Grayscale image; c) Enhanced image after denoising using DWT filtering; d) Image after applying Otsu's thresholding.

D. *Skull Removal*

The segmented image after Otsu's thresholding is taken as input to this stage. The skull removal means elimination of brain's non-cerebral tissues. There is a need to remove brain's skull portion as the skull portion is bright and its intensity is almost same as that of tumor and thus it can influence the segmentation of tumor.

In the proposed method, two basic morphological operators, erosion and di1ation are used for removing the skull portions. Dilation fills the holes and equalizes the contour lines. Erosion, on the other hand, eliminates the small objects and detaches the object joined by small bridge. These morphological operators are based on a structuring element, that serves as a small window and scrutinize the image. The choice of an appropriate structuring element is a must for proper removal of the skull portion [5]. The result of skull removal is shown in Figure 3.

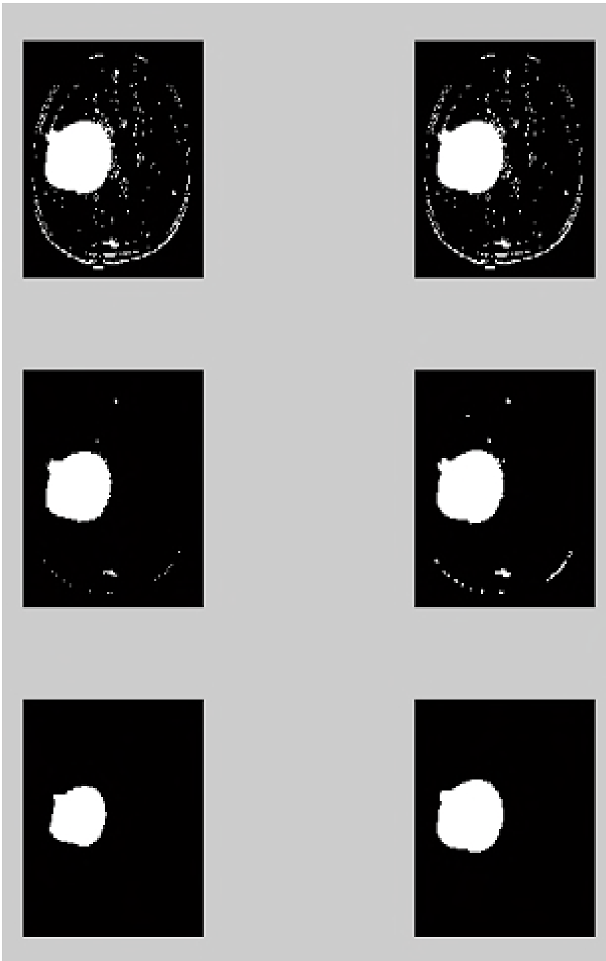

Figure 3. Skull removal after applying erosion (Left) and then dilation (Right) with structuring element 'disk' of radius 0,1,6 respectively from top to bottom.

E. Image Segmentation

Segmentation is the next important step to be carried out after image denoising and skull removal so as to precisely detect the tumor. Image Segmentation is the process of taking out the region of interest from an image by automated or semi-automated means [9]. There are various image segmentation methods such as watershed segmentation, thresholding, region growing, clustering, classification methods and so on [6].

In the proposed method, the image segmentation is performed using K-means clustering, an unsupervised method which is efficient and less prone to error and can be carried out with minimal data.

K-means [6] is an unsupervised method that divides the image into K- clusters on the basis of mean of each cluster. Initially, data is partitioned into K- clusters and thereafter mean of each cluster is computed. Each point is then added to the cluster having the minimum distance to the c1usters mean on the basis of Euc1idean distance. The final detected tumor after K-means segmentation is shown in Figure 4.

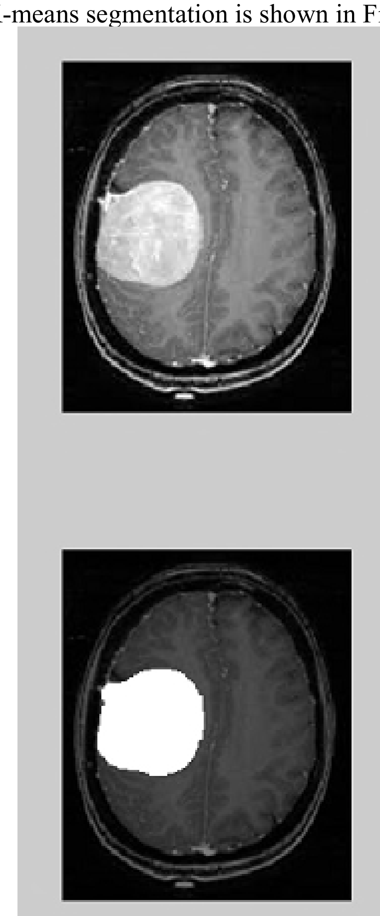

Figure 4: Final image of detected tumor using K- means segmentation.

IV. PERFORMANCE ANALYSIS

The proposed method is implemented on MATLAB (2010a) on a system having configuration Inte1 core 2 with processing speed 2.54 GHz, 2 GB RAM. There are various performance parameters for analyzing the images. The Peak Signal to Noise ratio (PSNR) [16] is one of the most important factor for analyzing the image. PSNR is the ratio of origina1 image to noiseless image. For denoising methods, PSNR average value ranges between 20-50 dB. The formula to calculate the value of PSNR is given in (1) where MSE is the Mean Square Error.

$$\text{PSNR}= 10*\log_{10} [(\text{MAX})^2/\text{MSE}] \tag{1}$$

The PSNR is used as a measure to reconstruct the image quality. The higher the PSNR value, the higher the image quality.

Mean Square Error (MSE) is another important measure for analyzing the image. MSE [16] is a risk function that corresponds to the expected value of squared error. The MSE is defined as:

$$\text{MSE} = 10*\log_{10} (\text{signal/noise}) \tag{2}$$

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The smaller the va1ue of MSE, the higher the image quality.

One more performance evaluation parameter is Bit Error Rate (BER) [17] defined as:

$$BER = 1/PSNR \quad (3)$$

The smaller the va1ue of BER, the higher the image quality.

The values of MSE, PSNR, BER obtained by the proposed method, when implemented on MATLAB are shown in Figure 5.

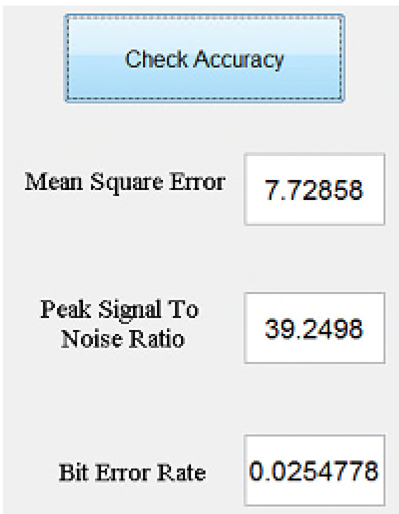

Figure 5: Result of MSE, PSNR, BER

The values of various performance parameters such as MSE, PSNR and BER obtained by the proposed technique are compared with the existing techniques in Table 1.

TABLE I. RESULT OF SEGMENTATION

Segmentation Techniques	MSE	PSNR	BER
Watershed Segmentation	2.0244	5.0677	0.19732
Region Growing Segmentation	9.5276	38.3749	0.02605
K-means and Otsu's Thresholding	7.7285	39.2498	0.02547

It can be observed from the Table 1 that the proposed method shows better results than the other existing methods. Here, the value of PSNR is more and the value of MSE and BER is less for the proposed method as compared to watershed and region growing segmentation.

V. CONCLUSION

Finding the accurate border of the area, comprising an identified brain tumor is a difficult task and needs to be addressed as it is applicable to many medical moda1ities and tumor types. In this paper, we proposed a new hybrid method using DWT, morphological operators, K-means and Otsu's thresholding technique for detecting and segmenting the tumor in the brain. The proposed method efficiently detects the tumor from the brain MRI images. The result of the proposed method is compared with the existing methods and it was found that the values of MSE and BER are less and value of PSNR is high as compared to the existing watershed and the region growing segmentation. Lower values of MSE and BER and high value of PSNR result in better image quality.

In the future work of this study, we will attempt to modify the proposed technique so as to classify the type of tumor as benign, malignant, or pre-malignant.

REFERENCES

[1] T. Lewis and S. Writer. Human Brain: Facts, Functions & Anatomy [Online]. Available: http:// www.livescience.com/29365-human-brain. html, [Retrieved: August, 2018].

[2] Anatomy of the Brain [Online]. Available: http://www.mayfieldclinic.com/PDF/PE- AnatBrain. Pdf, [Retrieved: August, 2018].

[3] A. Mandal. (2014, Apr 02). What is a Brain Tumor? [Online]. Available: http://www.news-medical.net/health/What-is-a-Brain-Tumor.aspx, [Retrieved: August, 2018].

[4] F. C. Harris, M. C. Gadiya, M. C. Motwani, and R. C. Motwani, "Survey of Image Denoising Techniques", Proc. GSPX, pp. 27-30, 2004.

[5] L. Ramya and N.Sasirekha, "A Robust Segmentation Algorithm using Morphological Operators for Detection of Tumor in MRI," *2015 IEEE International Conference on Innovations in Information Embedded and Communication Syststems ICIIECS 2015,* pp. 1–4, 2015.

[6] A. Norouzi et al. "Medical Image Segmentation Methods, Algorithms, and Applications," *IETE Technical Review June 2014,* vol. 31, no. 3, pp. 199-213, 2014.

[7] M. B. Ayed, A. Kharrat, and M. B. Halima, "MRI Brain Tumor Classification using Support Vector Machines and Meta-Heuristic Method," *International Conference on Intelligent Systems Design and Applications ISDA 2015,* pp. 446–451,2016.

[8] S. E. El-Khamy, R. A. Sadek, and M. A. El-Khoreby, "An Efficient Brain Mass Detection with Adaptive Clustered based Fuzzy C-Mean and Thresholding," *2015 IEEE International Conference on Signal and Image Processing Applications ICSIPA 2015,* pp. 429–433, 2015.

[9] Image Segmentation [Online]. Available: https://in.mathworks.com/discovery/image-segmentation.html, [Retrieved: September, 2018].

[10] N. N. Gopal and M. Karnan, "Diagnose Brain Tumor through MRI using Image Processing Clustering Algorithms such as Fuzzy C Means along with Intelligent Optimization Techniques," *2010 IEEE International Conference on Computational Intelligence and Computing Research ICCIC 2010*, pp. 694–697, 2010.

[11] R. G. Selkar and M. N. Thakare, "Brain Tumor Detection and Segmentation By Using Thresholding and Watershed Algorithm," *International Journal of Advanced Information and Communication Technology IJAICT 2014,* vol. 1, no. 3, pp. 321–324, 2014.

[12] A. Lakshmi, T. Arivoli, and R. Vinupriyadharshini, "Noise and Skull removal of Brain Magnetic Resonance Image using Curvelet transform and Mathematical Morphology,"

 ISBN: 978-1-61208-665-1

International Conference on Electronics and Communication Systems ICECS 2014, pp. 1–4, 2014.

[13] M. P. Beham and A. B. Gurulakshmi, “Morphological Image Processing Approach On The Detection Of Tumor and Cancer Cells,” *International Conference on Devices, Circuits and Systems (ICDCS), 2012*, pp. 350–354, 2012.

[14] R. C. Gonzalez and R. E. Woods, "Image Restoration," in *Digital Image Processing*, 2nd ed. New Jersey: Prentice-Hall, 2001, ch. 5, pp. 220-272.

[15] M. M. Sathik, S. A. Perumal, and S. K. Mohideen, “Image De-noising using Discrete Wavelet Transform,” *International Journal of Computer Science & Network Security (IJCSNS), 2008,* vol. 8, no. 1, pp. 213-216, January 2008.

[16] P. Kaushik and Y. Sharma, “Comparison of Different Image Enhancement Techniques Based upon PSNR & MSE,” *International Journal of Applied Engineering and Research, 2012,* vol. 7, no. 11, 2012. ISSN 0973-4562.

[17] G. Singh, S. Arora and V. K. Banga, “Comparison of F-measure, BER and PSNR of Tumor Detection using Hybridization of Fuzzy and Region Growing,” *International Journal of Computer Applications 2015,* vol.124, no. 3, pp. 32-38, August 2015.