Applied Mathematics & Information Sciences
An International Journal

http://dx.doi.org/10.12785/amis/090127

Fully Automatic Detections of Abnormalities of Brain MR Images by utilizing Spatial Information and Mathematical Morphological Operators

Arshad Javed[1,2,*], *Wang Yin Chai*[1], *Abdulhameed Rakan Alenezi*[2] *and Narayanan Kulathuramaiyer*[1]

[1] Faculty of Computer Science & Information Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
[2] Faculty of Computer Science & Information, Aljouf University, P. O. Box 2014 , Sakaka, Saudi Arabia

Received: 27 Mar. 2014, Revised: 27 Jun. 2014, Accepted: 28 Jun. 2014
Published online: 1 Jan. 2015

Abstract: Image segmentation refers to the process of partitioning a digital image into multiple sets of pixels are known as segments. The main goal of image segmentation is to change and simplify the representation of an image into something that is more meaningful and easier to analyze. The manual transactions for segmentation by experts is a difficult phenomena and time consuming process as well as. Most of the images in the process received are lacking of good quality. The main objective of this study is to develop a reliable mechanism to enhance the image quality and extract the abnormal portion through brain MR image accurately. A spatial filter is designed by utilizing the spatial information of the image and further to use collective information to enhance the poor quality of image(s), whereas, k-means clustering and mathematical morphological operations which extract the tumor segment from images. The proposed method is applied on different types of brain MR images for both visual and quantitative evaluations. Experimental results concluded during the practicum showed promising and reliable accuracy to open a thorough research for better future perspective of the technique developed in the article.

Keywords: Image segmentation, Morphological operators, Spatial mask

1 Introduction

In recent days, brain tumor is becoming a dreadful disease and spreading rapidly in all human societies throughout the world because of changing trends in human activities towards adopting unnatural and artificial means of life. This is causing to develop depressions which is supportive to brain tumors and if not diagnosed at an early stage in time can lead to colossal damage of body and brain and even to meet uncertain deaths before time in all ages of human beings. Medical reports and statistics of last few years show that brain tumor is becoming one of the alarming lethal disease and the experts have opinion that in future if not controlled, brain tumor might be one of the increasing disease for death rates.

It has been realized that one who suffers in brain tumor disease live in a complete paralyzed situation. Recovering such a person into normality demands us to pay him proper attentions through medical care and utilizing technical resources. Medical Experts use manual diagnostic method of segmentation of brain MR images which is very expensive, time consuming and non-repeatable process and this method although fulfills the needs but there are apprehensions of interpreting errors. For this purpose, there is an attempt in this article to design computer-aided diagnostic system which would help the experts to take a second opinion from the system which we are going to introduce below. Image segmentation is the process of splitting up an image into significant regions of particular problem which is required to be focused. It pertains with properties like gray level, color, shape, textures etc., help to recognize regions and distinguishing similarities. It then forms a spectrum and cluster very rarely possessing of ambiguity and more often with utmost clarity for building of groups of regions where each such group having a particular meaning to acquire result oriented accuracy for the physicians of this horrific disease.

On the other hand segmentation is the process of extracting points, lines or regions which are then used as

* Corresponding author e-mail: arsh_qau@ju.edu.sa

preliminary task for registration, measurement, movement, visualization, and analysis. Medical image segmentation is of vital importance in medical imaging. Accurate segmentation, in fact, is a subjective term for applying with medical point of view. Segmentation is, therefore, a primary step for medical images analysis. Commonly known that brain as an organ in human body is the central part that plays a pivotal role for all activities of a concerning individual to control and deliver actions. It is composed of complicated and perplex structure of bones and flesh which contains countless numbers of active and inactive brain cells that manipulate a system controlling nerves to process directions from the brain related to body response, effect on internal organs results of emotions and thoughts, recalling memories and storing new instruction maneuvered in the recent past and futuristic plans, and also controls movement of both internal and external organs accordingly as per set of instructions for the part to stimulate any further [1]. The brain tumor is rapidly growing disease which is not caused by viral infection but human activities are rather responsible for this disease into an individual throughout the world. To understand a brain tumor, it is the abnormal growth of cells in the brain. The normal brain works better and remains healthy if the growth of cells and percentage of deterioration of the cells in the brain are balanced. In case if the growth rate of new cells are less as compared to death rate of old cells or vice-versa then there appears a spot which causes swelling in the brain and this is what we know is a brain tumor. Now-a-days, the death rate is increasing due to brain tumor as cited in a combined research of the National Cancer Institute (NCI) and National Brain Tumor Foundation NBTF) of United States that approximately 42,000 people including both men and women in US alone suffers into brain tumor each year. Out of this, 29,000 people are recovered and 13,000 died [2]. The process of diagnosing brain tumor is a task of hard work to evaluate the presence of brain tumor, therefore, careful assessment is required before recommending brain tumor since any wrong conclusion can lead to severe damage in the life of an individual. However, survival of life must be important and hence every possible efforts are to be made sure before suggesting positive. Operating surgery for brain tumor is also a kind of very tough job for hours, intellect and skill because brain has a most complex structure in the body. Every cell in the brain is bounded together in a very complex way.

Magnetic Resonance Imaging (MRI) is a technique for medical imaging and radiologist use the methodology of this technique for visualizing the internal structure of the body [3]. MRI is a type of scan that is often used to help diagnose health conditions that affect organs, tissue, and bone. MRI provides rich information about human soft tissues anatomy. Magnetic resonance imaging (MRI) can be used to look at almost all parts of the body, but it is most often used to study the spinal cord and brain, the blood and heart vessels, other internal organs such as liver or lungs, joints, bones and breasts [4]. Brain is very complex in structure composed of cells or tissues which are tightly bounded with each other and supplies the blood. If the images are low contrast or poor quality then the diagnosis process can be affected and chances for the wrong diagnose become high. In the last few years, many computer-aided diagnosis systems have been developed using different techniques and methods to diagnose brain tumor which provide the random accuracy at different accuracy rates of lacking precision.

1.1 Salt & Pepper noise model

The *salt & pepper* noise also known as the impulse noise is frequently occurring noise in the MR images. This type of noise occurs usually by the faulty sensors of acquisition equipments like cameras or MRI machines. It can also occur due to timing errors at the digitization process of the image or by the faulty locations of memory cells. This type of noise creates the white spots in the dark regions of the image and that of black in the brighter regions. There are only two possible values of *salt & pepper* noise i.e. x and y, where x corresponds to white noisy pixel and y for black noisy pixel. For an 8-bit gray image, the typical value of white noisy spots is 255 and that for black noisy spots is 0. The probability density function (pdf) for salt & pepper noise is given by:

$$p(z)_{\text{salt \& pepper}} = \begin{pmatrix} x, & \text{for } g = a(\text{“salt”}) \\ y, & \text{for } g = b(\text{“pepper”}) \end{pmatrix} \quad (1)$$

The major objective of this study is to develop a fast, automatic, accurate and reliable system to extract maximum precision rate which not only help physicians to diagnose brain tumor but would also identify the region of brain tumor from brain MR images technique.

The remaining paper is divided in sections which are following: Section 2 is about related work which is closely related to current work and find out the problems. Section 3 provides the detailed methodology, in section 4 implementation is described. In section 5, results and discussion are explained. Conclusions are included in the section 6.

2 Literature Review

P. Vasuda [5] proposed a method to detect the tumor from MR images by using the fuzzy c-means algorithm. The main disadvantage of this method is that, the computational cost is high. One histogram based thresholding segmentation method is proposed by Yakoub Bazi [6]. This is global histogram based thresholding method. This technique segments background and objects using expectation-maximization algorithm assuming these two classes follow generalized Gaussian distribution. In this technique, initialization of the parameters is done using Genetic algorithm strategy that is its main limitation because this initialization takes more time. Koen [7] proposed an intensity based brain images segmentation method that segments the voxels of the brain. This method determines partial volume of each voxels of the image. On the basis of this information, segmentation of the brain MR image is achieved using Markov Random Field. For voxels that lies between overlapping regions of the tissues classes of brain does not accurately specify the partial volume because this model just deals with voxels that belong to specific one class. Karsten [8] proposed segmentation algorithm for brain segmentation using Markov random fields. This model is build upon the information of non-parametric distribution of tissue intensities, correlation of neighborhood and signal inhomogeneities that comes at the time of capturing MR images. The drawback of this method is that, the results achieved are based on iterative conditional model overlaps some gray matter regions with the white matter regions. M. Masroor [10] proposed a method for the segmentation of brain MR images by using the anisotropic filter and k-means algorithm. In this method morphological operators are used to extract the tumor portion. This method generates good results but the accuracy of results have not been validated.

The main drawback of some of the previous methods is that if the noise in the images exists then it affect on the segmentation process and accuracy. The other problem is that, most of the methods are computationally cost and takes large time to perform the segmentation process.

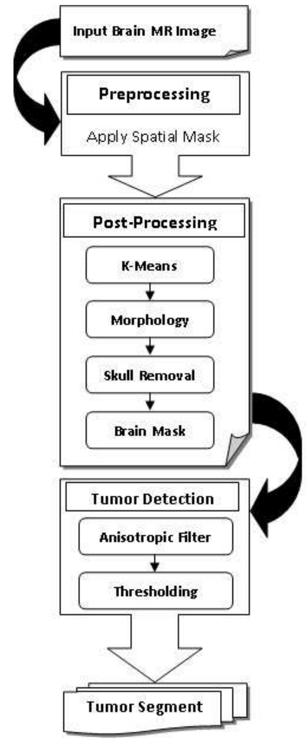


Fig. 1: System Flow diagram of Proposed Method

3 Methodology

The whole system is divided into many phases to detect the tumor from brain. First preprocessing step is performed on to the input image then post processing step is performed and in the last tumor portion is detected. The complete system flow diagram is given in the figure 1 and detail of major components is given one by one in the following subsections.

3.1 Preprocessing

Since noise in the image degrades the image quality and chances for the wrong diagnosis for the tumor detection becomes high, then it is necessary that the input image should be noise free. For achieving the best quality of image, first preprocessing step is performed to enhance the degraded image or quality. For this purpose a spatial mask is designed by utilizing the spatial information of the image.

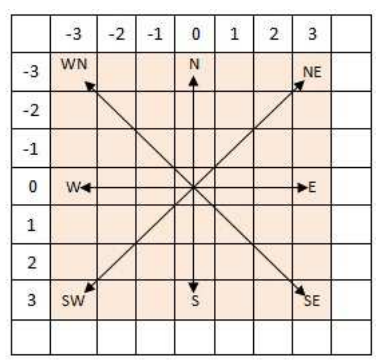
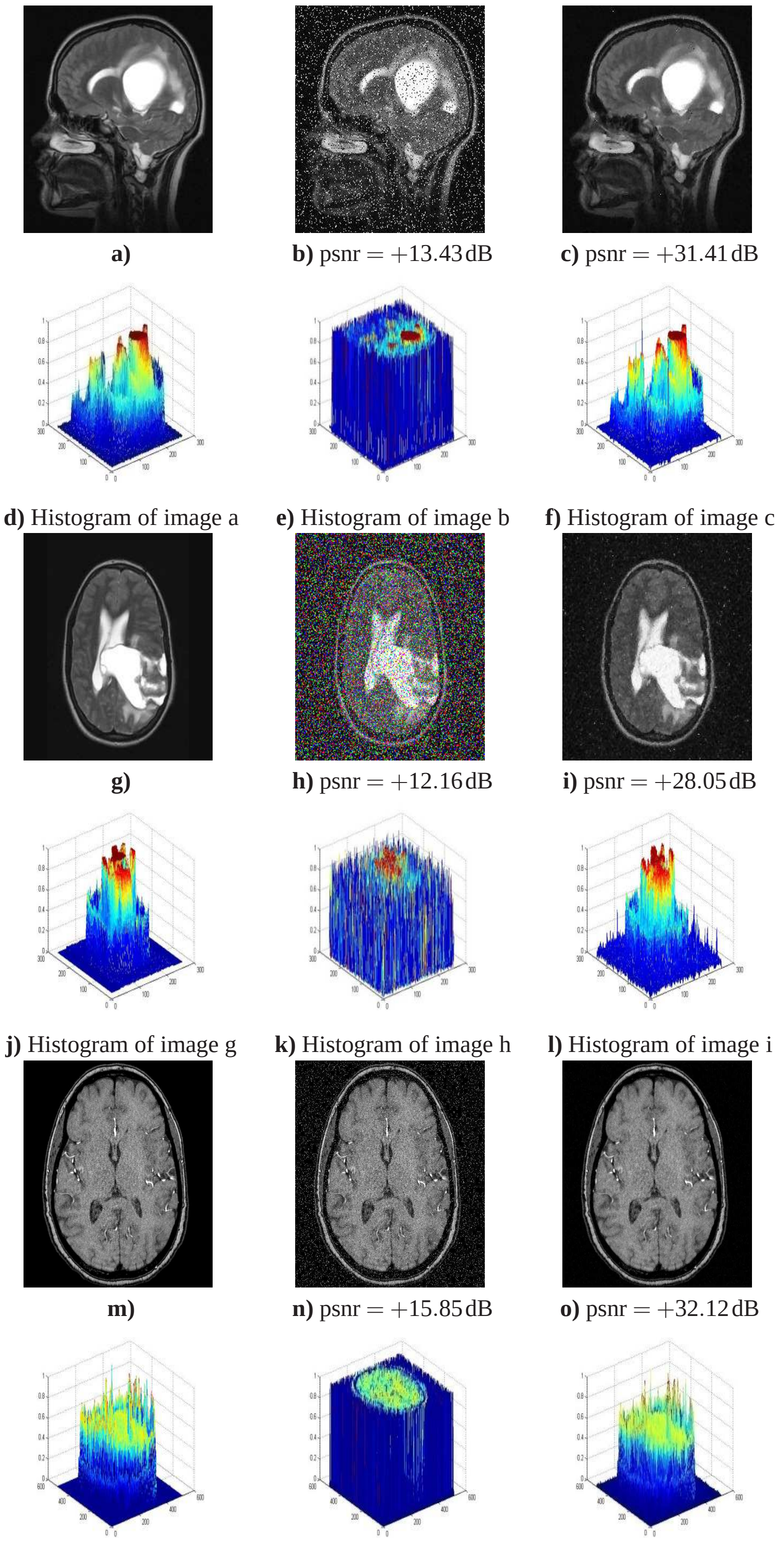


Fig. 3: 7×7 directional window

3.1.1 Spatial Mask for Image Enhancement

One of the significant attribute of a digital image is that the neighboring pixels have close resemblance with each other in terms of correlation. Having the advantage of this digital image characteristic, a spatial mask is designed to enhance the poor superiority of the image. A 7×7 squared window was used throughout this work.



a) **b)** psnr = +13.43 dB **c)** psnr = +31.41 dB

d) Histogram of image a **e)** Histogram of image b **f)** Histogram of image c

g) **h)** psnr = +12.16 dB **i)** psnr = +28.05 dB

j) Histogram of image g **k)** Histogram of image h **l)** Histogram of image i

m) **n)** psnr = +15.85 dB **o)** psnr = +32.12 dB

p) Histogram of image m **q)** Histogram of image n **r)** Histogram of image o

Fig. 2: (a,g,m). Original image (b,h,n). Noisy image (c,i,o). De-noised image with spatial mask

$$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 2 & 2 & 2 & 1 & 1 \\ 1 & 1 & 2 & 2 & 2 & 1 & 1 \\ 1 & 1 & 2 & 2 & 2 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Fig. 4: 7×7 spatial mask

Suppose S_k denotes the set of coordinates aligned with kth centered at (0,0), where $k = 1,2,3,4$, i.e.

$$\begin{aligned} S_1 &= \{(-3,-3),(-2,-2),(-1,-1),(0,0)(1,1),(2,2), \\ &\quad (3,3)\}, \\ S2 &= \{(0,-3),(0,-2),(0,-1),(0,0)(0,1),(0,2),(0,3)\}, \\ S3 &= \{(3,-3),(2,-2),(1,-1),(0,0)(-1,1),(-2,2), \\ &\quad (-3,3)\}, \\ S4 &= \{(-3,0),(-2,0),(-1,0),(0,0)(1,0),(2,0),(3,0)\}. \end{aligned} \quad (2)$$

Let $S_k^0 = S_k \setminus (0,0)\, \forall k = 1,2,3,4$ and $d_{i,j}^{(k)}$ denotes the directional index, then

$$d_{i,j}^{(k)} = \sum_{s,t \in S_k^{(0)}} W_{s,t} |y_{i+s,j+t} - y_{i,j}| \quad (3)$$

$$W_{s,t} = \begin{cases} 2 & s,t \in \Omega^3 \\ 1 & \text{Otherwise} \end{cases} \quad (4)$$

$$\Omega^3 = \{(s,t) : \; -1 \le s,t \le 1\}$$

In a 7×7 window which is centered at (i, j), for every direction

– $d_{i,j}^{(k)}$ is the sum of all absolute difference of gray level values between $y_{i+s,j+t}$ and $y_{i,j}$ where $s,t \in S_k^0$.
– Considering, if two pixels having the small spatial distance then their gray level values should be close.
– We weight the absolute differences between two nearest pixels with some higher value W_m before calculating the sum.
– If W_m have very large value, it causes that $d_{i,j}^{(k)}$ is mainly decided by the differences which correspond to W_m. So we used $W_m = 2$ (the reciprocal of distance ratio).
– Every direction index is sensitive to the edge aligned with a given direction.

By using the above concept, we designed the spatial mask for the image enhancement and this mask is given in the figure 4.

3.2 Post-processing

3.2.1 *K*-Means Clustering

For the segmentation and binarization point, k-means [10, 11] clustering algorithm is applied to the image for the required purpose. K-means algorithm begins with an initial estimation for the selection of centroids of each class presented in the image. After this selection, each element of the image is assigned to a group with similar properties within this subject to have closest distance with its center. The centroids are then re-calculated after each assignment and this process is continued until each point is assigned to the clusters. Like other optimization problems which have some objective, K-means algorithm is also aimed at the minimization of objective function which is given as:

$$J_{obj} = \sum_{j=1}^{k} \sum_{i=1}^{n} x_i^{(j)} - c_j{}^2 \quad (5)$$

Where $x_i^{(j)} - c_j$ correspond to the distance between a data point $x_i^{(j)}$ and cluster center c_j. Figure 5 indicates to the segmented binarized image by applying k-means algorithm with and without the image improvement.

3.2.2 Morphological Operations

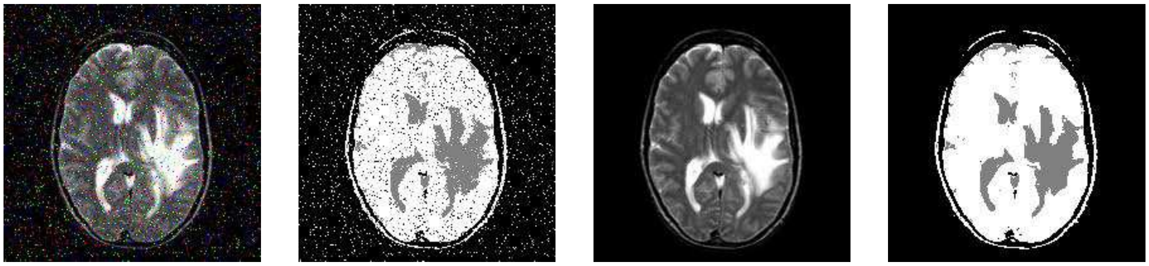
Morphological operations are performed when there are some imperfections during the process of segmentation like connections of background and foreground objects and need to remove them. After applying the mathematical morphological operations, a mask for the brain is generated and then this is mapped with the original image to remove no region of interests hard tissues from the brain. Since, the tumor exists in the brain soft tissues regions, so, as a result only soft tissues reside in the brain segment. The following mathematical morphological operations are performed for this purpose:

$$\begin{aligned} &\text{Opening:} && A \bigcirc B = (A \ominus B) \oplus B && (6) \\ &\text{Closing:} && A \cdot B = (A \oplus B) \ominus B && (7) \\ &\text{Erosion:} && A \ominus B && (8) \\ &\text{Dilation:} && A \oplus B && (9) \end{aligned}$$

Where A, B indicate to the image and structuring kernel respectively. A disc shaped structuring element having the radius 7 is utilized throughout this work. The consequence of morphological operations is shown in figure 6.

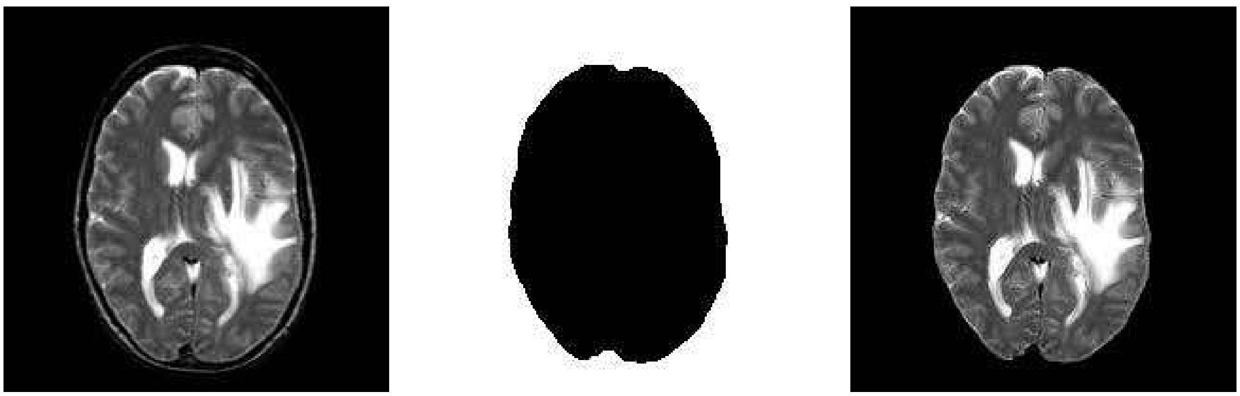
3.3 Tumor Detection

After getting rid of the skull hard tissues from the image, anisotropic diffusion filter [12] designed by researchers Perona and Malik was applied to make the image smoother. Since, this filter is specially designed to provide the better smoothness and preservation of the edges of the objects of the image in an enhanced way, therefore, this filter is also applied for this cause. Anisotropic filter provides the smoothness to the edges of



a) b) c) d)

Fig. 5: (a). Input image (b). Segmented by *k*-means before enhancement (c). Enhanced image by spatial mask (d). Segmented by *k*-means after enhancement



a) b) c)

Fig. 6: (a). Input image (b). Brain mask after morphological operations (c). Skull removed image

Table 1: Comparison of results of image enhancement

Dataset	%age of noise (σ)	PSNR of Noisy image	PSNR of Restored image		
			Average filter	**Median Filter**	**Proposed Method**
#1	5	+18.55	26.11	30.66	**33.41**
#2	6	+18.26	25.32	30.01	**33.09**
#3	7	+17.01	24.98	29.76	**32.23**
#4	8	+16.67	24.15	29.21	**31.98**
#5	9	+15.33	23.46	28.67	**31.56**
#6	10	+14.32	23.11	28.12	**31.11**
#7	11	+12.49	22.43	27.89	**30.66**
#8	15	+10.64	22.19	27.44	**30.06**
#9	20	+9.16	22.02	27.13	**29.97**
#10	25	+8.92	21.45	26.22	**29.73**

Table 2: System performance in terms of time

Patient	**Data size** (Pixels)	**Detection time** (Seconds)
#1	512×512	1.18
#2	512×512	1.21
#3	512×512	1.14
#4	256×256	0.89
#5	256×256	0.84
#6	256×2564	0.92
Total Average time		**1.03**

image without lasting any finer and significant detail of the image. After acquiring the image smoothness, a global thresholding method was used to extract the information of the tumor portion. The extracted information of the tumor segment is shown in figure 7.

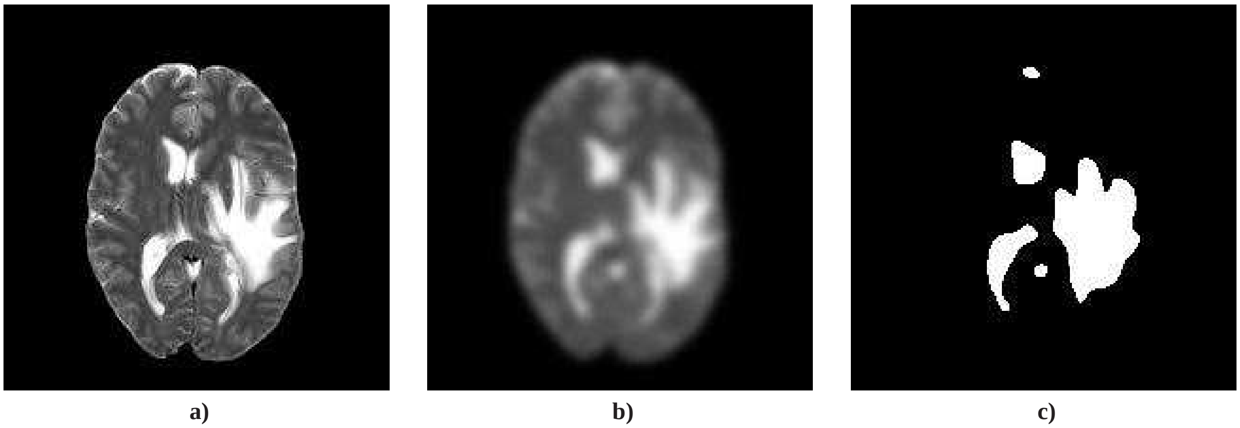


Fig. 7: (a). Skull removed image (b). Anisotropic filtered image (c). Tumor extracted

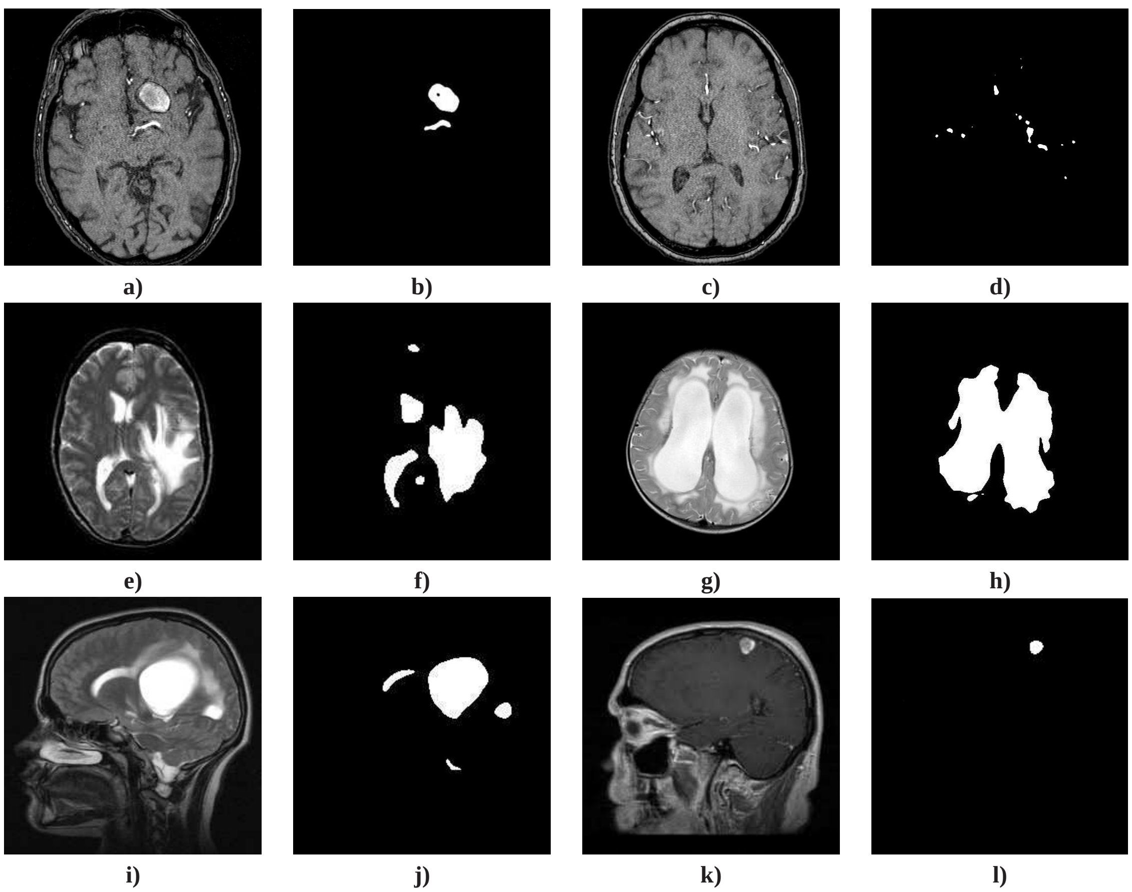


Fig. 8: Visual Results of Proposed Method (a), (c), (e), (g), (i), (k). Input images, (b), (d), (f), (h), (j), (l). Tumor extracted images by proposed method

Table 3: Results Validation by KB Method

Patient	GT by Expert #1		GT by Expert #2		Mean of Expert 1 & 2	
	%Match	CR	%Match	CR	%Match	CR
#1	98.85	0.79	99.79	0.81	99.32	0.8
#2	98.43	0.81	98.17	0.85	98.3	0.83
#3	96.91	0.84	96.21	0.83	96.56	0.84
#4	97.62	0.8	98.42	0.92	98.02	0.86
#5	98.11	0.89	98.34	0.78	98.23	0.84
#6	99.33	0.89	99.26	0.92	99.3	0.91
				Total Average	**98.29**	**0.85**

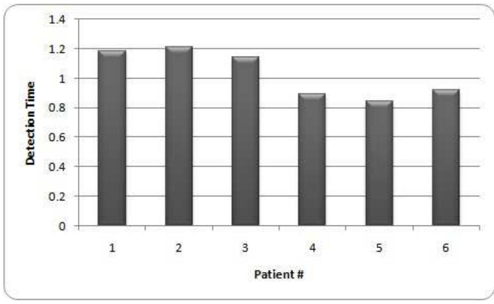


Fig. 9: System time performance graphically

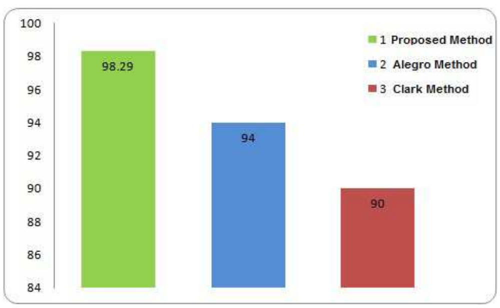


Fig. 10: Accuracy Comparison

4 Implementation

The proposed system is implemented using the matlab®7.8 software installed on pentium 4 machine having dual core with windows 7 operating system. The entire flow of the process of proposed method is given in figure 1.

For initiating the diagnosis process, the brain MR image which has to be processed is given as input to the system. The spatial filter which is specially designed for reducing the noise and enhancing the image quality is applied to the input image. After achieving this task, k-means clustering technique was applied to segment the image and for the binary format conversion purpose. To overcome the problem of imperfections occurred during the segmentation process, some mathematical morphological operations were performed. After this process, a brain mask is generated which only covers all the soft tissues resided in the brain. Then this prepared brain mask is mapped with the original image to get rid of the skull and hard tissues from the brain. *Perona & Malik* Anisotropic diffusion filters is applied to the cortex stripped removed image to make the image more smoother. Simply in the last global thresholding technique was applied for the extraction of the tumor segment information from the brain.

5 Results and Discussion

Though, the proposed method is tested on a wide variety of the brain MR images with a varying complexity, however the experimental results shown only covers few images which are from one of them. Figure 8 highlights some visual results of the proposed system. The quantitative or experimental results are calculated by using the method knowledge-based (KB) validation known as KB method. For experimentation, a database was formed by selecting randomly the suitable images acquired by six different patients. These selected images were then sent to two experts having experience and connected with this field to mark the boundary of the affected portion of the brain manually.

5.1 Knowledge Based (KB) segmentation validation method

The knowledge based (KB) [13] method is widely used for measuring the segmentation results. This method measures the results with facts which is known as ground-truth (GT). The results are calculated on the basis of Correspondence Ratio (CR) and Percent Match (%Match) between system detected tumor portion and ground-truth tumor labeled portion. The CR and %Match are defined as

$$CR_{avg} = \frac{TP - (0.5 * FP)}{\text{No. of GT pixels}}$$

Where TP stands for True Positive i.e. affected pixels indicated both by system and ground-truth, FP for False

Positive i.e. system indicates the damaged pixels while ground-truth not. The CR value estimates that how much difference is there in the segmentation process from the ground truth. 1 indicates the ideal value for CR.

$$(\%\text{Match})_{\text{avg}} = \frac{\sum_{i=1}^{\text{slices in set}} (\%\text{match})_i * (\text{No. of GT pixels})}{\sum_{i=1}^{\text{slices in set}} (\text{No. of GT pixels})_i}$$

The Higher values of percent match (%Match) specify the greater similarity of segmented regions between system generated and ground-truth.

Table 3 shows the experimental results of the proposed method. The average %match of the tumor portion with ground-truth is 98.01 and average CR is 0.84. The recent former techniques which are presented by M. C. Clark [13] and Alegro [14] are 90 and 94 respectively. The average %match of the proposed method is 99 which an improvement over the previous techniques. Table 3 shows the average calculated CR and %Match, figure 10 shows the comparison of results of proposed method. For measuring the performance of the system in terms of time, the proposed method performs the segmentation process in few seconds when applied on the selected database of the images. Table 2 shows the tumor detection time of the proposed method and this time is also shown graphically in figure 9. Figure 2 shows the image enhancement with spatial mask which is specially designed for the enhancement of image quality. For testing purpose, first the salt & pepper noise is added in the image and then retrieved by the spatial designed mask. For measuring the quality of the enhanced image, a global criteria which is known as PSNR (Peak signal-to-noise ratio) is calculated. Considering the standards, if PSNR of any image is contained within the range of 25-35 dB, this image is considered to be of good quality. The proposed method improves the image quality within this standard range. Table 1 highlights some image enhancement results by utilizing the spatial information. The quantitative/ experimental results showed that the proposed system performs the segmentation process in a fast, efficient, accurate and improved way.

6 Conclusion

In this paper an effort is made to develop strong, efficient, fast, and fully automated system. This system would serve the dual purposes; (1) to attain accuracy of confirming brain tumor and (2) to identify the exact region and location of tumor in the brain just in a time process of few seconds. Brain MR image techniques saves the time of days into seconds and therefore provide great support to medical experts to diagnose the abnormalities in the brain.

Time bracket that the physician avails from concentrating over the shadowed and haze slides would lead him/ her to focusing more on disease fast remedies.

During the process, at first the poor quality image is enhanced using the spatial information. This further updates each pixel of the image by considering neighborhood of the pixel. Then the k-means segmentation clustering technique is applied for segmentation the image. Finally, by applying some mathematical morphological operators and thresholding technique, tumor portion is extracted from the brain MR image.

The analysis are performed on the extracted abnormal segment of the brain by considering the ground reality. The area of the detected tumor portion is compared with the ground-truth and results are calculated for precision measurement.

Interestingly that the accuracy and efficiency of the said proposed method found to be amazingly very promising and high speed tool in the diagnosing of brain tumor.

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Arshad Javed was born on 1977 and is currently a PhD student at University Malaysia Sarawak, Malaysia. He received his Master degree in 2003 in Computer Science from Quaid-e-Azam University Islamabad, Pakistan. His research interests are image processing.

Wang Yin Chai is a Professor with Faculty of Computer Science and Information Technolgy, University Malaysia Sarawak. He received his PhD degree in 1997 in GIS from University Sains Malaysia. His research interests are in Content Based Image Retrieval System, Transmission Dynamics of Plasmodium Falsiparum

Abdulhameed Rakan Alenezi is currently dean of Faculty of Computer Science and Information, Aljouf university, Saudi Arabia. He received his PhD degree in 2008 from University Utara Malaysia with major e-learning. His research interests are e-learning.

Narayanan Kulathuramaiyer is currently a Professor & dean of Computer Science at the Faculty of Computer Science and Information Technology, Universiti Malaysia Sarawak. He received his Ph.D. in Computer Science from Graz University of Technology, Austria. His research interests include Semantics-Aware Systems, Knowledge Management (Governance), Technology Assimilated Learning and Web Science.