An Algorithm for Detecting Brain Tumors in MRI Images

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Abstract— **In this paper, a computer-based method for defining tumor region in the brain using MRI images is presented. A classification of brain into healthy brain or a brain having a tumor is first done which is then followed by further classification into begnin or malignant tumor. The algorithm incorporates steps for preprocessing, image segmentation, feature extraction and image classification using neural network techniques. Finally the tumor area is specified by region of interest technique as confirmation step. A user friendly Matlab GUI program has been constructed to test the proposed algorithm**.

Keywords-brain tumor; image segmentation; feature extraction; neural networks

I. INTRODUCTION

Magnetic resonance imaging (MRI) is considered now as an important tool for surgeons. It delivers high quality images of the inside of the human body. One should be careful when dealing with sensitive organs like the brain. A brain tumor is any intracranial mass created by abnormal and uncontrolled cell division. Tumors can destroy brain cells or damage them indirectly by causing inflammation, compressing other parts of the brain, inducing cerebral edema or by exerting internal pressure as they grow [1]. Brain tumors are classified into:

- Primary brain tumor.
- Secondary (metastatic) brain tumor.

Primary brain tumors, whether benign (noncancerous) or malignant (cancerous), may be localized or extended while secondary tumors could be in different locations.

Many research contributions for detection of brain tumor from MRI images were introduced [2, 3, and 4].
In this paper, new system is proposed for detecting brain tumor, it also classifies if it is a primary or secondary tumor. It is suggested to be used as a second decision for the surgeons and radiologists.

The paper is organized as follows. In Section 2, image segmentation techniques are applied. Seven methods are compared to get a method with the best details of the brain tissue. Feature extraction methods used is explained in section 3. In section 4, neural network classifiers are employed. In section 5, the proposed algorithm for the detection of brain tumors is presented. The simulation and results are presented in section 6. Finally, a conclusion warps the paper

II. IMAGE SEGMENTATION TECHNIQUES

An important step in image analysis is the segmentation. Segmentation methods are divided into eight categories namely; thresholding approaches, region growing approaches, classifiers, clustering approaches, Markov random field models, artificial neural networks, deformable models, and atlas-guided approaches. In this research, several of approaches belong to the categories mentioned above were tested such as K-means and Expectation Maximization algorithms, Entropy method and Adaptive threshold method, region growing approaches, and Canny edge detection. Among these methods adaptive threshold approach and canny edge detection methods were found to be more suitable than other as segmentation methods in giving details of the brain tissue leading to identify a tumor region in the brain. For image segmentation, the authors tried 2 different algorithms; Canny edge detection and adaptive thresholding. The nature of MRI brain images makes these algorithms of sufficient accuracy. Thus, there was no need to investigate more sophisticated image segmentation algorithms

The adaptive threshold technique [5] is applied to the original MRI image illustrated in Fig.1. It is based on a simple concept, a parameter called θ defines the brightness threshold is chosen and applied to the image pixels to deliver the binary image shown in Fig.2.

The goal of edge detection is to mark the points in a digital image at which the luminous intensity changes sharply. Sharp changes in image properties usually reflect important events and changes in properties. The Canny edge detection operator, developed by John F. Canny in 1986 [6], uses a multi-stage algorithm to detect a wide range of edges and involves the following steps:

- Smooth the image with a Gaussian filter,
- Compute the gradient magnitude and orientation using finite-difference approximations for the partial derivatives,
- Apply non-maxima suppression, with the aid of the orientation image, to thin the gradient-magnitude edge image,

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- Track along edges starting from any point exceeding a higher threshold as long as the edge point exceeds the lower threshold.
- Apply edge linking to fill small gaps

Applying canny edge detection technique to the MRI image in Fig.1, the result is shown in Fig.3.

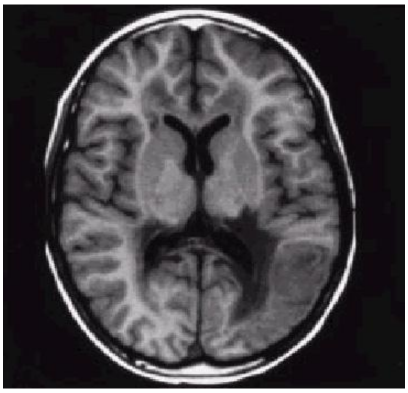

Fig.1. The original MRI Brain image

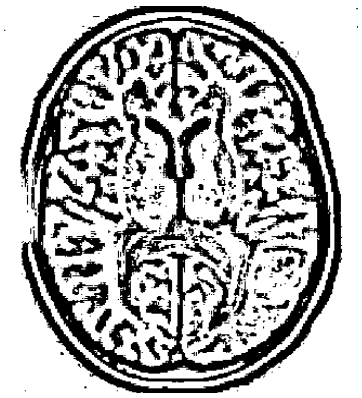

Fig.2. The segmented image using Adaptive threshold method.

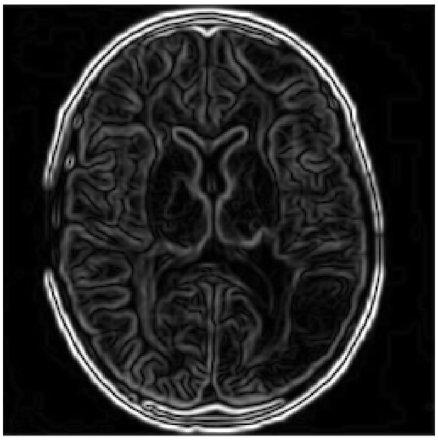

Fig.3. Brain image after applying Canny edge detector

Since such techniques give satisfactory results as they show all the details of the brain tissue, they have been chosen as a segmentation algorithm for which one of them gave the best recognition rate.

III. FEATURE EXTRACTION

Feature extraction methods are used to get the most important features in the image to reduce the processing time and complexity in the image analysis. One of the features extraction methods is LOG-Lindeberg algorithm [7] which follows these steps:

- Read the image.
- Number of blobs detected.
- Calculate Laplacian of Gaussian parameters.
- Calculate scale-normalized laplacian operator.
- Search of local maxima.

Applying LOG-Lindeberg algorithm to the original MRI Brain image shown in Fig.1 the resulting image is shown in Fig.4.

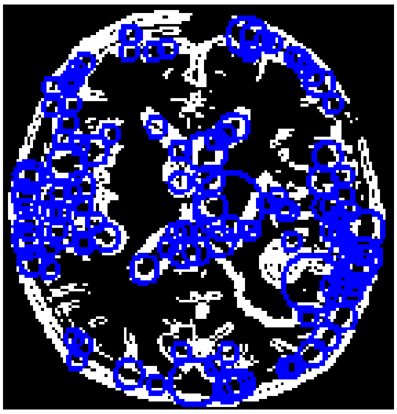

Fig.4. The feature points of the segmented image are in blue.

Another method is Harris-Laplace. It relies heavily on both the Harris measure and a Gaussian scale-space representation [8]. The algorithm follows these steps:

- Find the image parameters.
- Scale these parameters.
- Find the Harris feature.
- Compute the Laplace.

Fig.5 shows the result of applying Harris-Laplace to the segmented image is n in.

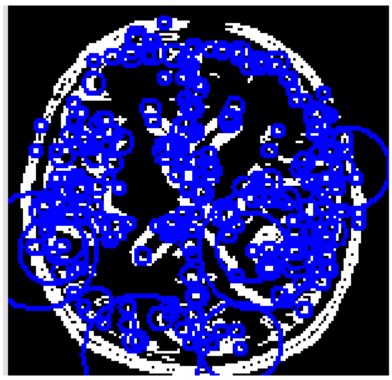

Fig.5. The feature points of the segmented image are in blue.

Harris algorithm is a third feature extraction method, which consists of the following steps:

- Find luminance value.
- Set derivative masks.
- Find derivative image.
- Sum of the Auto-correlation matrix.
- Find interest point response.
- Set a threshold as a one percent of the maximum value.
- Find local maxima greater than threshold.
- Build interest points.

The delivered image by applying Harris algorithm to the segmented image is illustrated in Fig.6.

Fig.6. Feature points of the segmented image using Harris algorithm " in blue"

This method gives features inside and on the boundary of the tumor with the test images. It gave a good result with all of tested images.

IV. Classification using Neural Networks

In classification tasks, there are often several candidate feature extraction methods available. The most suitable method can be chosen by training neural networks to perform the required classification task using different input features (derived using different methods). The error in the neural network response to test examples provides an indication of the suitability of the corresponding input features (and thus method used to derive them) to the considered classification task

V. The Proposed Tumor Detection Technique

The proposed system is suggested to be used as a second decision to the radiologist and surgeon. It detects tumors in MRI brain images and it defines the tumor type. The system consists of seven stages, which are image pre-processing, image segmentation, image gray levels number, feature extraction, neural networks classifiers, ROI extraction, and decision device. Fig.7 shows a flow chart of the steps for the proposed system

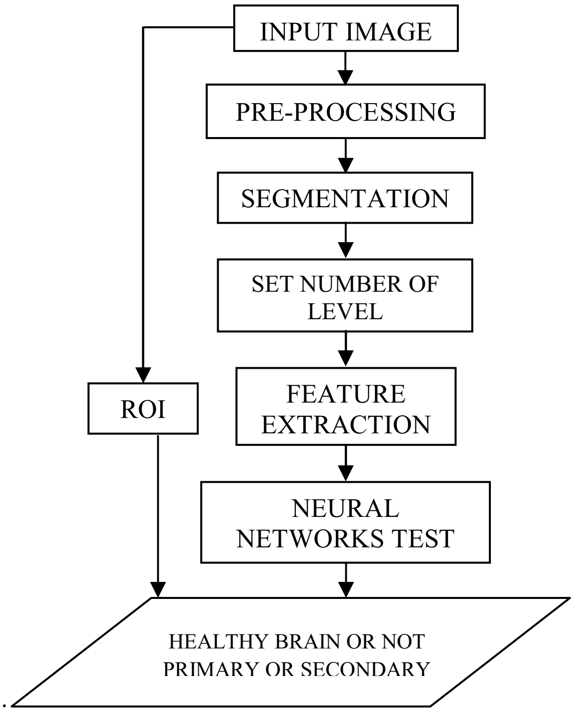

Fig.7. The proposed system flow chart.

The first step in the algorithm is a pre-processing for the brain image. In this step, the brain boundary is expanded to fill the input image size and the image size is changed to be 256x256, also the gray level is expanded to be from 0 to 255 if it occupies less than that. Then segmentation follows; in this step the image is segmented using the canny edge detection technique or adaptive threshold technique. After that it goes to the level numbering stage, in which the segmented image is represented by certain level number. Two levels are chosen for simplification. With the Canny edge detection technique, the image is represented in two levels (black and white). With the adaptive threshold technique, this step is neglected because the output image is a binary image. Characteristic feature are then extracted. Harris method is used because it gives good results with the test images. The fifth stage is a neural networks stage in which two neural networks are used. The first neural network is used to classify brains into healthy brain or brain with tumor while the second neural network is employed to define the tumor type. Each one of them is a 3 layers simple feed forward network. The number of neurons in the input layer is 240 with 2 neurons in the output layer and 15 neurons in the hidden layer two different threshold functions are used for the networks. The Log-sigmoidal non-linearity function is used between the input layer and hidden layer while the saturated linear output function is used between the hidden and output layer. A neural network starts by initializing the weights and bias randomly. The neural network is trained using Levenberg-Marquardt algorithm. There are two most common error options namely the Mean Absolute Error (MAE) and the Mean Squared Error (MSE). The last step is the ROI whereby the tumor location is defined by using unsharp contrast enhancement filter. In healthy brains the output is the brain boundary. The system also gives a message when it fails to analyze the image. This is done because of the threshold value of the output of the neural network. This threshold is 0.75. It means the system will give a result if it sure 75%.

VI. Results and Simulation

All the brain images used in this work are obtained from the internet as no database was available to us, they are 102 images. All test images are first classified by a specialist [9] into normal brain and brain with primary or secondary tumor. Normal brain images are 70 images, primary tumor brain images are 12 images and secondary brain images are 20 images. There are 18 images which cannot be identified the tumor type. 54 images are used to train the neural network and 48 images are used to test the system.

The whole system is programmed using MATLAB© and user friendly GUI is constructed to perform all functions. Two sets of neural networks had to be trained. The input features for the first set were based on Canny edge detection, whereas the input features to the second set were based on adaptive thresholding. The obtained recognition rates are illustrated in Table 1. Much better and accurate results are obtainable if the database size increases. Fig.8 through Fig.11 show the whole system detecting the healthy brain and tumor brain.

The proposed system recognition rates are listed in Table 1. Two rates are listed for each neural network. For the first neural network, the two rates are the rate of falsely diagnosing a healthy brain as a brain with tumor and the rate of falsely diagnosing a brain with tumor as a healthy brain. Similarly, for the second neural network, the two rates are the rate of falsely diagnosing a malignant tumor into benign and the rate of diagnosing a benign tumor into malignant.

The authors would like to comment that the zero percent listed in the table does not mean that there is no error in general but there is no error in the test images that are used (because of the lake of available MRI brain images, the test images contains only 16 images of brains with tumors, 6 of them are benign and 10 are malignant).

Table 1. Recognition rates of the proposed system

Technique	Neural network 1		Neural network 2	
	falsely diagnosing a healthy brain as a brain with tumor	falsely diagnosing a brain with tumor as a healthy brain	falsely diagnosing a benign tumor into malignant	falsely diagnosing a malignant tumor into benign
Canny edge detection and Harris	18.75%	0%	10%	0%
Adaptive threshold and Harris	15.625%	6.25%	0 %	0%

VII. Conclusion

A new system that can be used as a second decision for the surgeons and radiologists is proposed. It determines whether an input MRI brain image represents a healthy brain or tumor brain as percentage. Further, it defines the tumor type; malignant or benign tumor. It consists of seven stages; pre-processing, image segmentation, feature extraction, neural network, ROI and decision. The obtained correct recognition is satisfactory in view of the available limited data base.

References

[1] "The essential guide to brain tumors", National brain tumor society (NBTS), 2007. www.braintumor.org/upload/contents/330/GuideFINAL2007.pdf

[2] R. Ratan and S. Sharma, "Brain Tumor Detection based on Multi-parameter MRI Image Analysis", ICGST-GVIP Journal, ISSN 1687-398X, Volume (9), Issue (III), June 2009.

[3] Mrigank Rajya Sonal Rewri Swati Sheoran, "Application Of Fuzzy System in Segmentation of MRI Brain Tumor", (IJCSIS) International Journal of Computer Science and Information Security, vol. 8, no. 1, April 2010.

[4] Qurat-ul-Ain, M. Arfan Jaffar, "An Automated system for Brain Tumor Detection from MRI images", First international e-health conference 2010 http://www.ehap.net.pk/Conference_Presentations.html

[5] Ridler, T.W. and S. Calvard, "Picture Thresholding using an iterative selection method", IEEE Trans. on Systems, Man, and Cybernetics, 1978. SMC-8(8): pp. 630-632.

[6] Canny, J., "A Computational Approach to Edge Detection", IEEE Trans. Pattern Analysis and Machine Intelligence, Vol 8, Issue 6, pp 679-698, 1986.

[7] Tony Lindeberg, "Feature Detection with Automatic Scale Selection", Int. J. of Computer Vision, 1998. vol 30, no. 2, pp 77-116, 1998

[8] M. Malshe, R. Narulkar, L. Raff, M. Hagan, S. Bukkapatnam, P. Agrawal, and R. Komanduri, "Development of generalized potential-energy surfaces (GPES) using many-body expansions, neural networks (NN), and moiety energy (ME) approximations", The Journal of Chemical Physics, May 2009. 14; 130 (18): 184102.

[9] Dr. Mohamed El Naseh, radiologist in Tiba hospital Alexandria, Egypt. Personal communication

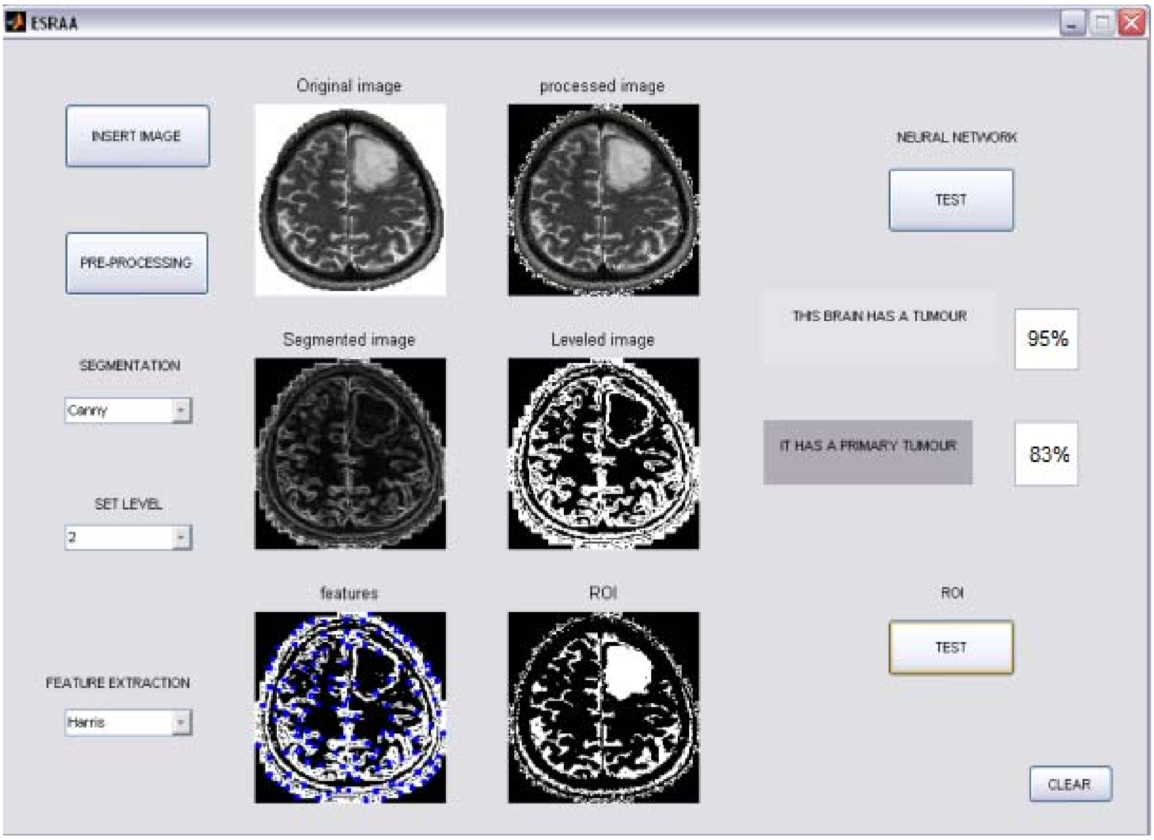

Fig.8. The GUI program screen: the system detects a benign tumor.

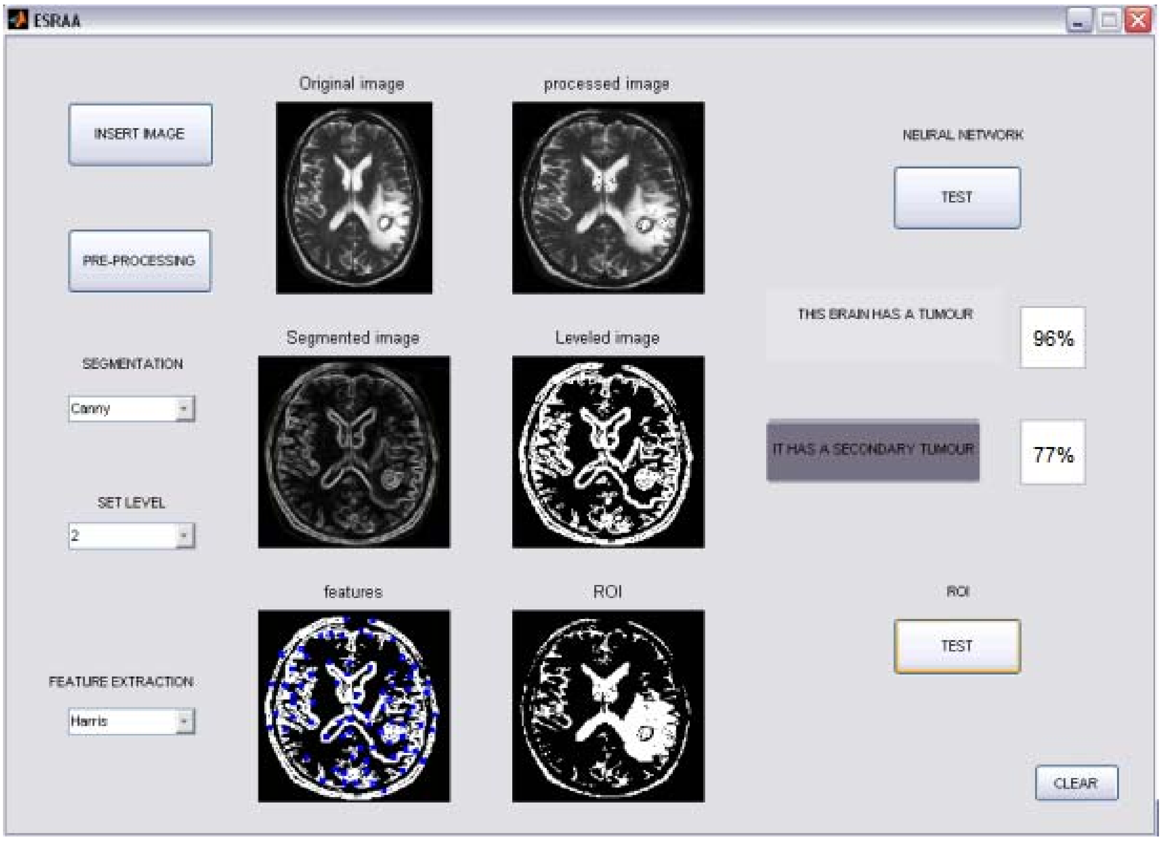

Fig.9. The system detects a malignant tumor.

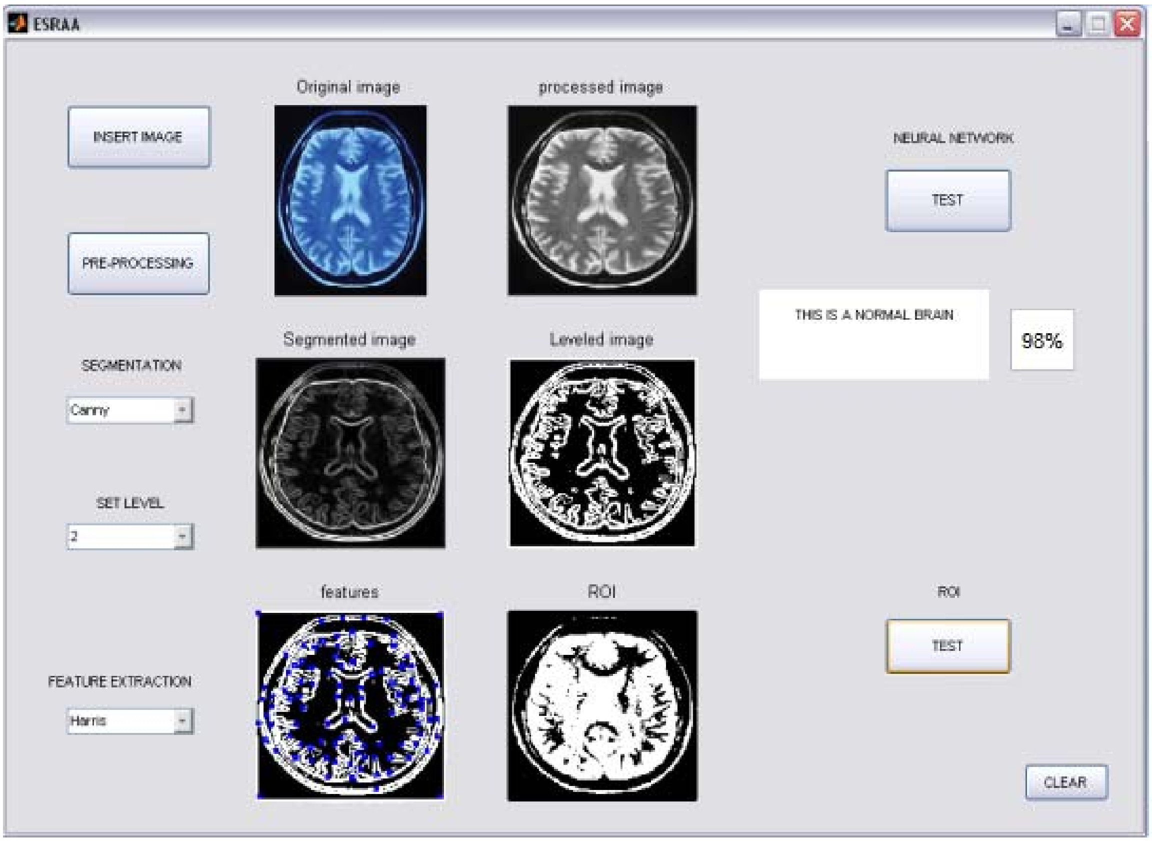

Fig.10. The system detects a normal brain.

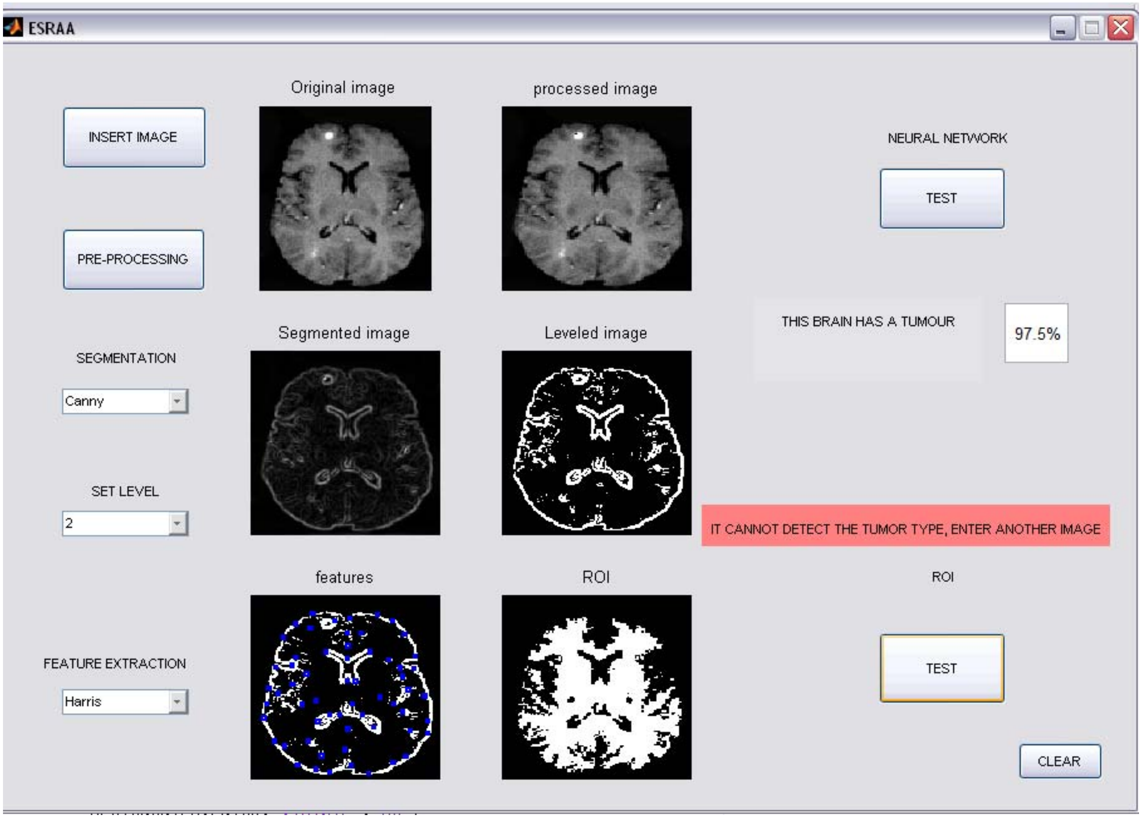

Fig.11. The system can't analyze the type of the tumor for a given image.