Intelligent Brain Hemorrhage Diagnosis Using Artificial Neural Networks

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***Abstract*—Brain hemorrhage is a type of stroke which is caused by an artery in the brain bursting and causing bleeding in the surrounded tissues. Diagnosing brain hemorrhage, which is mainly through the examination of a CT scan enables the accurate prediction of disease and the extraction of reliable and robust measurement for patients in order to describe the morphological changes in the brain as the recovery progresses. Though a lot of research on medical image processing has been done, still there is opportunity for further research in the area of brain hemorrhage diagnosis due to the low accuracy level in the current methods and algorithms, coding complexity of the developed approaches, impracticability in the real environment, and lack of other enhancements which may make the system more interactive and useful. Additionally many of the existing approaches address the diagnosis of a limited no of brain hemorrhage types.**

This project investigates the possibility of diagnosing brain hemorrhage using an image segmentation of CT scan images using watershed method and feeding of the appropriate inputs extracted from the brain CT image to an artificial neural network for classification. The output generated as the type of brain hemorrhages, can be used to verify expert diagnosis and also as a learning tool for trainee radiologists to minimize errors in current methods. The prototype developed using Matlab can help medical students to practice the related concepts they learn using an image guide with examples for surgeries and surgical simulation. System was evaluated by the domain experts, like radiologists, intended users such as medical students as well as by technical experts.

The prototype developed was successful since it was being evaluated as credible, innovative and useful software for the students in the field of radiology while 100% of the evaluators mentioned the diagnosis accuracy is acceptable.

Keywords; Medical Image Processing, Neural network, Watershed, fuzzy c means, Intelligent Brain Hemorrhage Diagnosis

I. INTRODUCTION

Brain hemorrhages; also termed cerebral hemorrhages, intracranial hemorrhages or intracerebral hemorrhages by their types; is a type of a stroke which is caused by an artery in the brain bursting and causing bleeding in the surrounded tissues. . "The Dana guide to Brain Health"[1] states, in each year cerebral hemorrhages are affecting 7 people out of every 100,000 in the west while 220 out of every 100,000 in Asia. The statistics have shown that there is a higher risk for brain hemorrhages to Africans, Asians and Hispanics in the United States than the Whites. It also says that women tend to be affected more than men by a ratio of 3 to 2. High blood pressure, alcohol usage, and smoking are known risk factors while heredity also plays a major role in causing brain hemorrhage. Additionally more than 80% of people are suffering due to being born with weak spots in their major brain arteries. [1].

However according to medical specialists' early diagnosis of the condition and obtaining immediate and relevant treatment can be a lifesaver for affected patients. The main techniques and tools which help in diagnosing of this disease is the human brain Computed Tomography [CT] image obtained from the CT scan and an expert such as an experienced doctor who will be able to extract the important symptoms of the disease from the image by naked eye.

Aim of this research is to design, develop and evaluate an easy to use, intelligent and accurate system which enables users like radiologists or medical students as well as doctors to feed brain CT images and to diagnose whether there is a hemorrhage and specify the type of hemorrhage if one exists using Fuzzy C means and Watershed Algorithm along with neural network for hemorrhage classification.

II. CURRENT METHODS

Manual Systems

Computerized Tomography [CT] or Computerized Axial Tomography [CAT] will be used to obtain the CT images. This is based on a combination of X-rays as they can be passed through the different parts of a patient's body. Varying amount of X-rays will be passed through and exit the body depending on the amount that can be absorbed in a particular tissue such as a muscle or lung. During conventional X-ray imaging, the existing X-ray will interact with a detecting device, which contains X-ray film or other image receptors to provide a two dimensional image of the required part of the patient's body. CT will use a rotating X-ray device and detectors to make a slice. [2]. Magnetic resonance imaging [MRI] is based upon signals resulting from water molecules, which contains between 70% and 80% of the average human brain. There are two types of MRI scanners.

- T1 [anatomical] which is fast to acquire, with excellent structural detail [e.g. white and gray matter].

- T2 [pathological] which is slower to acquire, therefore usually lower resolution than T1. Best approach for finding lesions. [3]

Comparing both CT and MRI images, MRI is the most frequently used method for brain imaging and related research. At the same time bones can be well segmented in CT data using simple thresholding techniques because of the contrast between the bones and the surrounded tissues. In contrast, soft tissues are not well recognized in CT images and thresholding is inadequate. Similarly there are alternate reasons for using CT scan regarding the following:

- Patients who are too large for the MRI scanner may have to go through the CT scanner.
- Claustrophobic patients and those with metallic or electrical implants may have issues in going through MRI scan.
- Patients who are unable to remain motionless for the duration of examination due to age, pain or medical conditions will also have to go through CT scans excluding MRI scans.

III. RELATED RESEARCH

With the technological improvement in artificial intelligence, image processing, neural networks and genetic technology etc universities and other research centers all around the world, started doing research on integrating this medical expertise with a computer aided system. Thus, much research was done in brain image segmentation using [Magnetic Resonance] MR and CT scan images in order to diagnose brain hemorrhages in the past three decades up to date. As indicated in [4], Delo *et al.* [1985] has used a thresholding and a region growing method to study on brain segmentation on CT data. The Fuzzy C means algorithm [FCM] algorithm was used in Li *et al.* [1993] to segment brain MRI scan while Bayesian classification was used in Laidlaw *et al.* [1994] to identify the distribution of different materials in MRI volumetric datasets of the brain. And Wells *et al.* [1996] was able to propose EM segmentation for MR brain images for the first time. Again, as discussed in [5] Ham and Prince [1999] extended the traditional FCM used in Li *et al.* [1993] to represent the quality of MR images obtaining process while in the same year in a multi-resolution simulated annealing for brain image analysis was done. Since we felt some of the algorithms are too complex and have the mentioned drawbacks as discussed in the previous section, it is better to investigate the possibility of using a different approach.

In the next decade starting from 2000, frequent approaches in brain image segmentation for diagnosis of brain hemorrhages and strokes were taking place. As reviewed in [6] in Maksimovic *et al.* [2000] a common approach which uses active contours was used while in the next year Cuadra *et al.* 2001] gave an overview of the research on MR brain segmentation. Several methods for segmentation and quantification of brain tumors which can be done manually, user assisted by medical experts and fully automatic methods [6] were done while [7] indicates a common approach including methods such as fuzzy connectedness and expectation-maximization was done by Liu *et al.* As further discussed in [7], two X-ray energy levels used by dual energy CT scanners allow radiologists for better differentiation and characterization and isolation of body tissues and fluid as demonstrated in Ying *et al.* [2006] In Liu *et al.* [2006] Alternative Fuzzy C-means [AFCM] for medical image segmentation was used. In the last two years, other researchers [5] found another reliable method of image segmentation which uses genetic algorithm for segmentation of Brain CT images.

Even though a lot of research on medical image processing has been done, we believe that, still there is room for further research in the area of brain hemorrhage due to the low accuracy level in the current methods and algorithms given above, coding complexity of the developed approaches such as simulated annealing algorithms, impracticability in to the real environment when calculations are being done according to the genetic biological values [5] and lack of other enhancements which may make the system more interactive and useful. [8] Additionally most of the approaches have been taken in diagnosing a few limited types of brain hemorrhages such as Intracerebral Hemorrhage [9].

IV. APPROACH AND ALGORITHM

The overall design of this system consists of six major modules. Figure 1 describes the flow between these modules.

- Once the brain CT soft image is converted in to a jpeg, the image will be uploaded to the system.
- Then in the next module, image will be preprocessed in order to get a clear image to be processed in the segmentation module.
- The image segmentation module will isolate the objects in the brain image, in order to extract features of each object in the next module.
- Set of image processing activities will be carried out to super impose the image with the required features.
- Then the unnecessary noise and objects will be removed if it is needed and will mark the objects that will be used to extract features.
- The features will be extracted to feed the neural network as an input to train or recognize the type of the hemorrhage.
- Finally the type of the hemorrhage will be identified according to the trained neural network which is being created in the training phase of the system.
- Once the network is created, saved network can be used for training of the next images once the input features are extracted and output result is generated using the previously created network file.

- If the user is satisfied with the result, user will be able to add the test image to train the system to gain better output the next time. A new network file will be created once a successful training is done. According to the results generated in the plot, user will be able to decide whether the training percentage is better or to try out once again just by training the system with the same input and output features

System implementation can also be divided in to three sections as below.

A. Preprocess Image

Image is preprocessed by performing the following steps:

a) Resizing the image is done so it fits on the system user interface.

b) Convert in to grey scale image to make it contrast.

c) Convert in to two dimensional image.

Once, image was segmented to mark the foreground objects. For that the following steps were carried out.

B. Segement the Image Dilate the Image

a) Morphological Techniques
   a. Opening- by-reconstruction
   b. Closing- by-reconstruction
   c. Complement image
   d. Calculate regional maxima
   e. Superimpose the image

b) Compute Background Markers

c) Watershed Transformation and the Segmentation

d) Visualize the Result

e) Remove Background Noise

The image will be segmented to identify the relevant objects in the CT scan and to retrieve the values needed as input. Once the image is segmented properly, required information will be extracted to feed the neural network.

C. Extract Features for ANN

The following information will be extracted.

- Number Of Objects
- Area of the Number Of Objects

✓ Eg., If an ICH hemorrhage brain CT Image is given as depicted in figure 2

- Objects = Separated Hemorrhage and Skull
- Number of Objects = 2

✓ Eg., If an SDH hemorrhage brain CT Image is given as depicted in figure 3 ,

- Objects = Skull with the attached hemorrhage
- Number of Objects = 1

Therefore the extracted data will be categorized as depicted in table 1 to feed the neural network.

D. Train the System

In the first training, set of input images will be taken from a given location to extract input features and the known output will be found by naming the images from the type of the hemorrhage.

Then the 'net' file can be generated using a train tool for the first time after going through few testing iterations by providing the saved input and output files.

We used 'nprtool' of Matlab as the network pattern recognition training tool to generate the 'net' file for the first time and coded the necessary sections to use once the system is going to train for a test image.

Number of hidden neurons, percentage of the training, test and validation images will be defined before the training after a successful testing. The testing executed is explained in the next section.

Since the neural network starts with random initial weights, the results will differ slightly every time it is run. The random seed is set to avoid this randomness using rand method.

Once the input features are calculated and the vector is created, to add the image to train, the output will be defined according to the value that has been received as the output result.

Once the input and output files are saved, system can be trained with them. This logic can then be used to train the tested images as well.

V. TESTING

Two sets of images for various numbers of hidden neurons were tested. The two sets were,

- A set of 31 training images which is in a total of 70%, 7 validation images which is in a total of 15% and 7 training images which is a total of 15% were tested for 5, 10, 15, 20 and 25 hidden neurons
- A set from 35 training images which is a total of 80%, 5 validation images which is in a total of 10% and 5 training images which is in a total of 10% were tested for 5, 10, 15, 20 and 25 hidden neurons.

As stated in [22] it is always better to have lower values for MSE/mean Squared Error and %E.

It is always better to have maximum non confusion for training, validation and testing set of images since the training is done using them.

After consideration of the above facts, using, 35 samples [80%] for testing, 5 samples [10%] for validation and 5 samples [10%] for testing using 15 hidden neurons are proved to be the best training set of images classification over the other results gained by the author.

Following figure 4 depicts the results gained for the above set of sample images after using 15 hidden neurons.

Figure 5 depicts the system's main user interfaces and how it works.

VI. EVALUATION AND CONCLUSION

System was evaluated by technical and non technical people under five categories which are domain experts, intended users, technology experts, professors and experts in Matlab. The concept was found to be highly innovative by the majority of the evaluators from all the categories. Even the non technical users found this concept "useful" after explaining that the user need not be technical to handle the application after the initial set up. Also it was mentioned that Matlab is the wiser choice to simulate and perform functionalities of the system while the use of neural network is the best option of the available technologies of its kind since the accuracy of the predictions improves in magnitude with the amount of sampling data.

As future enhancements, we identified some of the comments given by the evaluators. Some of them are explained below with the solution that we hope to provide in a later implementation

1. Implement the proposed system in a manner that it supports diagnosis of other type of hemorrhages as well.

The proposed system could be taken in to the next level by implementing identification for EDH and SAH. Feature extraction can be done as below:

- Number of Objects
- Area of the Objects
- Histogram of the objects
- Convex and Vertex point's distances

Using the above features, ICH, SDH, EDH and SAH can be categorized for set of training data. Since the SDH and EDH is similar in the number of objects and area calculations, the features considered in this system will not be enough. Therefore the Convex and Vertex point's distances can be measured.SAH can be identified using the histogram values of the objects since it is widened all over the background.

ICH can be recognized with the number of objects, area and the histogram values.

2. Improve the system so it can support for brain tumors, and cancers as well.

E.g., Brain tumor can be recognized from the roundness of the objects inside the background.

3. Improve the system so it can support in a web interface.

During the evaluation phase, according to the comments received, we were recommended to implement a web interface so the system can be accessible from any places. This can be implemented using HTML so it can be browsed. [22]. We hope to attempt these in a later implementation.

In its present state the system can be utilized by medical experts to verify their decisions and also as a learning tool by trainees in the medical field.

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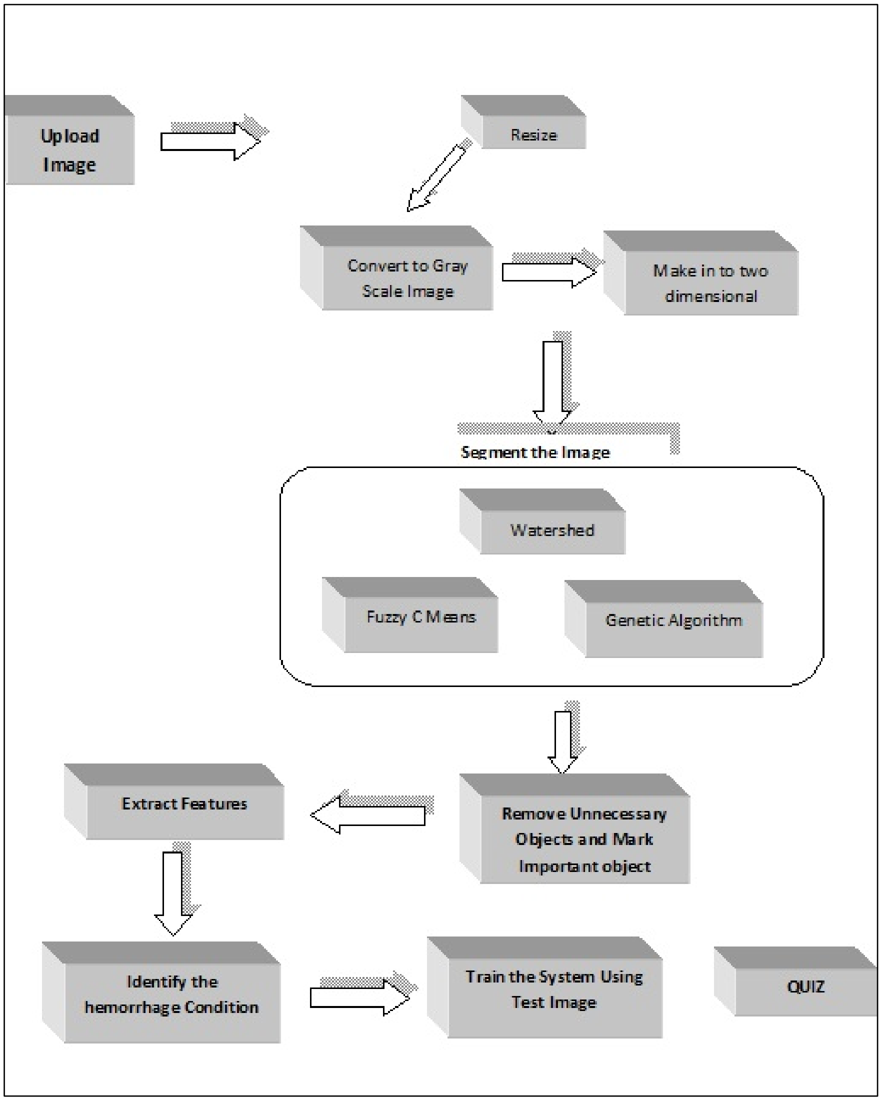

Figure 1. Design Diagram

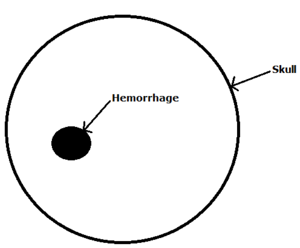

Figure 2 : Design of a ICH Hemorrhage

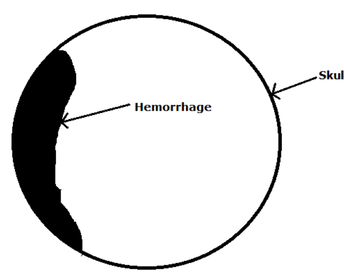

Figure 3: Design of a SDH Hemorrhage

Hemorrhage Condition	Logic	Input Feature Set for ANN	Output Feature Set [sent in the first training and sent when expecting the result]
Normal	NoOfObjects = 1 and Area < SDH Area	[NoOfObjects, Area[Obj1], 0]	[0,0,1]
ICH	NoOfObjects = 2	[NoOfObjects, Area[Obj1], Area[Obj2]]	[0,1,0]
SDH	NoOfObjects = 1 and Area > Normal Area	[NoOfObjects, Area[Obj1], 0]	[1,0,0]
Wrong Image	NoOfObjects > 2 || NoOfObjects = 0 and too much colour	Error Message	-

Table 1: Logic for the input feature set

No Of Hidden Neurons	Input types	No Of Samples	MSE – Mean Squared Error	%E – Percent Error	Non Confusion Percentage	Total Non Confusion Plot %
15	Training	35 – 80%	4.75256e-3	0	100%	97.8%
	Validation	5 – 10%	2.59340e-6	0	100%	
	Testing	5 – 10%	1.33326e-1	20.00000e-0	80%	

Figure 4. Best Performance Result in Testing

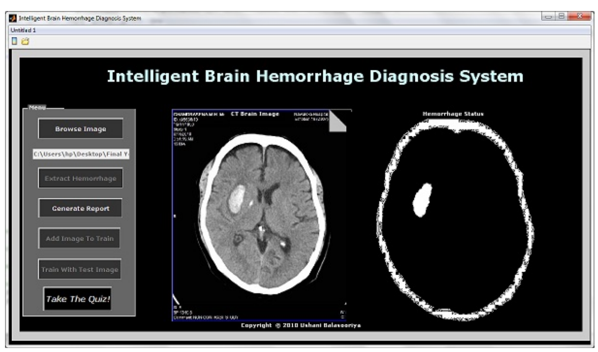

Figure 5. Brain, skull with the hemorrhage