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Sensitivity and Accuracy Comparison of the Algorithms for the Abnormality Extraction of the MRI Slice Images of a GUI based Intelligent Diagnostic Imaging System

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ABSTRACT
Intelligent diagnostic Imaging System (IDIS) is a developing imaging modality that is beginning to show promise of detecting and characterizing abnormalities of the brain. The abnormalities of the brain are due to Intracranial Neoplasm, Cerebral Infections and Inflammations, Stroke, Cerebral Aneurysms, Vascular Malformations, Central Nervous System Trauma and Neurodegenerative Disorders. The abnormalities are detected mostly by scanning the brain. MRI is an effective technique to find the abnormalities of the brain. This paper is concerned with the development of image processing tools and intelligent algorithms that will automatically detect the abnormalities of the brain and sensitivity and accuracy comparison of the Algorithms for the of abnormality extraction.

General Terms
Algorithm, Threshold, Abnormality Extraction

Keywords: Graphical User Interface (GUI), Intelligent Diagnostic Imaging system (IDIS). Magnetic Resonant Imaging (MRI), Central Nervous System (CNS), Cerebro-Spinal Fluid (CSF), Fluid Attenuating Inversion Recovery (FLAIR).

1. INTRODUCTION
The purpose of abnormality extraction is to understand and identify the abnormality which is very helpful for the physician to gain knowledge of the severity of the disease. Region based segmentation is used for this purpose. In abnormality extraction, the threshold detection is very important and it can be considered as the key feature of the Intelligent Diagnostic Imaging System. Image segmentation means partitioning an image into meaningful regions with respect to a particular application. The segmentation is based on measurements taken from the image and might be grey level, colour, texture, depth or motion. Usually image segmentation is an initial and vital step in a series of processes aimed at overall image understanding. Different algorithms are used for T1 and T2 MRI Images. MATLAB tools are used to do the segmentation. The intensity level of a particular abnormality is same in an MRI image slice. It can be iso-intense, hypo-intense or hyper-intense [1]. In this work, the abnormality has been extracted using different segmentation methods like Region Growing, Region splitting and Merging and Marker-Controlled Watershed Segmentation [2]. Then most pertinent segmentation method is selected and GUI is developed to see the abnormality and diagnose the abnormalities. After getting the information of abnormalities from the developed algorithm, the results are compared with the doctor's diagnosis report.

The image processing methods that will helps the development of Intelligent Diagnostic Imaging System are Filtering, Restoration, Segmentation, Reconstruction, Registration and Pattern Recognition [3]. Proper filtering methods can be adopted to remove the unwanted signal intensities and motion artifacts. Normally MRI scan sequence lasts for half an hour to two hours. It is very difficult to make the scan without motion artifacts. Because of the patient movement, blur images, overlapped or unclear images may result. One of the options is to repeat the scanning process. If the motion artifact is not severe then image restoration methods can be used. If some abnormalities are found by using image registration or some other means, then from each slice of axial, coronal and sagittal planes, the abnormalities can be segmented and reconstructed to get correct size and shape of abnormalities. The normal slice thickness is 5mm. We count the number of slices in axial, coronal and sagittal direction where the abnormalities are present. Then we multiply the number of slices with the slice thickness in axial, coronal and sagittal direction. This will give volumetric information of the abnormalities. By using the segmented abnormalities from each slice and slice thickness we can reconstruct the abnormalities [4]. This will help the surgeon in his surgery. The image registration is done on a slice image with same slice image with contrast. This will give clear cut information about the abnormalities present in that slice, if the slice image is abnormal. By using pattern recognition we can recognize whether the abnormality is a tumor or infarction or edema or hemorrhage. It can also be realized whether the tumor is malignant or benign. Benign tumors are well circumscribed tumors.

A Graphical User Interface (GUI) is a graphical display that contains devices, or components, that enable a user to perform interactive tasks. To perform these tasks, the user of the GUI does not have to create a script or type command line. Often, the user does not have to know the details of the task at hand. A GUI is a pictorial interface to a program. A good GUI can make programs easier to use by providing them with a consistent appearance and with intuitive controls like pushbuttons, list boxes, sliders, and menus etc. The GUI should behave in an understandable and predictable manner, so that user knows what to expect when he or she performs an action. However GUIs are harder for the programmer because a GUI-based program must be prepared for mouse clicks (or keyboard input) for any GUI element at any time. Such inputs are known as events, and a program that responds to events is said to be event driven. In event driven programming, callback execution is asynchronous, controlled by events external to the software. Each component, and the GUI itself, are associated with one or more user-written routines known as callbacks. The execution of each callback is triggered by a particular user action such as a button push, mouse click, selection of a menu item, or the cursor passing over a component. GUI is a program interface that takes advantage of the computer's graphics capabilities to make the program easier to use. Well-designed graphical user interfaces can free the user from learning complex command languages. The integrated GUI has its own embedded operating system containing Hyper Text Markup Language (HTML) which is built into the hardware of the device. The embedded micro-HTML inside the integrated GUI is the key component. So, basically, "in the box" the customer receives the embedded micro-HTML, application-specific controller chip, and an LCD controller. There is no need for third-party compilers or operating systems to be tested. So, GUI is used to enhance the application in a particular medical device.

2. SEGMENTATION

Literature review, MRI Study and Clinical Study are carried out to understand the area over which the objectives are framed and the work is carried out. A detailed study of medical imaging, MRI techniques and analysis of MRI data was carried out from the year 1996 to 2010 to understand the techniques for abnormality extraction and diagnosis. More than three hundred selected cases of Brain MRI were studied at K. S. Hegde Medical College, Mangalore. Around 20% of the cases are found to be normal while others have some abnormalities.

Many segmentation methods are studied and applied. Region growing method i.e. region based segmentation is well suited for the segmentation of the abnormalities of clear intensity changes [5]. Around 90% of abnormalities have clear intensity changes. Present threshold detection for Regional Growing Segmentation method is not up to the level for abnormality extraction [6]. Therefore two new algorithms were developed for threshold detection for Regional Growing Segmentation method and they are found to gives excellent results. Thus, the Regional Growing Segmentation with automatic seed point and threshold detection algorithms (J&K 1 and J&K 2 algorithms) are the best method for extracting the abnormalities of the MRI Images and it is found that the new algorithms are better than the existing technology. Finally Graphical User Interface (GUI) has been developed and utilized to see the result of a diagnostic Imaging system in an easy way. MATLAB based GUI is studied and developed for proper functioning of IDIS. GUI is used for reading the image slice by slice, extraction of the abnormality, Diagnosing the abnormality and displaying the result.

2.1 Monochrome Image Segmentation

Biomedical Images such as X-ray, Ultrasound, CT and MRI images are generally monochrome Images. Segmentation algorithms for monochrome image are generally based on discontinuity and similarity. In the first category, the approach is to partition an image based on abrupt changes in intensity, such as edges in an image [7]. Point, Line and Edge detection are based on this category and it is not helpful in the case of extraction of the abnormalities from MRI images [8]. The second segmentation category that can be used effectively to extract the abnormalities from the MRI images is based on partitioning an image into regions that are similar according to a set of predefined criteria [9]. Region based segmentation and segmentation using the watershed transform come under this category.

2.2 Region-Based Segmentation

2.2.1 Region Growing

Region growing is a procedure that groups pixels or sub regions into larger regions based on predefined criteria for growth. The basic approach is to start with a set of "seed" points. Then from these seed points grow regions by appending to each seed those neighboring pixels that have predefined properties similar to the seed. Two new algorithms were developed, J&K 1 for T1 and J&K 2 for T2 to find the global threshold for Region growing segmentation algorithm.

Threshold is based on the analysis of the histogram and represents the difference between 255 and the location of the valley point decided by the algorithm in case of J&K 2 and difference between 0 and the location of the valley point for J&K 1. Find the maxima of each subsection. A moving window of size 10 is moved from higher intensity level to the lower intensity level in an overlapped manner of 5 intensity level and finds the maxima (pixel) from each window position. For J&K 2, the maxima values are analyzed from high intensity side to the low intensity side. For J&K 1 it is vice versa. If two consecutive maxima are identical and left and right maxima from the identical maxima are decreasing in magnitude then the identical maxima whose intensity level are same can be consider as a hill point. The space between the two hill point is divided into three region and finding the valley point of each section. If all the valley points satisfy a predefined criteria then left most valley point is considered for J&K 2 as main valley point and rightmost valley point is considered for J&K 1. The main valley point is subtracted from 255 to get the threshold in J&K 2 and difference between 0 and the valley point gives the threshold in J&K 1.

2.2.2 Region Splitting and Merging

In Region Splitting and Merging, an image is initially subdivided into a set of arbitrary, disjointed regions [10]. Then the regions are merged and/or split in an attempt to satisfy the conditions stated by the predicate P.

2.3 Marker-Controlled Watershed Segmentation

Direct application of the watershed transform to a gradient image usually leads to over-segmentation due to noise and other local irregularities of the gradient [11]. Over-segmentation can be controlled based on the concept of markers. A marker is a connected component belonging to an image. We would like to have a set of internal markers, which are inside each of the objects of interest as well as a set of external markers, which are contained within the background. These markers are then used to modify the gradient image. Various methods have been used for computing internal and external markers, many of which involve the linear filtering, nonlinear filtering, and morphological processing. The MATLAB functions with syntax to set the internal markers and watershed transform are

Im=**imextendedmin**(f, 2); fim=f; fim(im)=175;

Lm=**watershed**(bwdist(im)); em=Lim==0;

3. Comparison of different Segmentation Methods

MRI images can be classified mainly in to T1 and T2 images [12]. The algorithms used for T1 and T2 images (J&K 1 and J&K 2 algorithms) are different and are developed by the author. By using these algorithms more precise threshold can be found. threshodep_modt1 and threshodep_modt2 are author defined functions using J&K 1 and J&K 2 algorithms. Around 99% of abnormalities of T1 and T2 images can be correctly extracted using the new algorithms.

After working with many samples, it is found that using Region Growing Segmentation algorithm with automatic seed point and author defined threshold functions (collectively called as J&K 1 and J&K 2 algorithms), the abnormalities are precisely extracted. Author defined functions threshodep_modt1 and threshodep_modt2 succeeded in about 99% of cases. graythresh MATLAB M function succeeded only for 30 to 40 percentage of cases of T2 images only. graythresh failed in T1 images.

If the image contains hypo and hyper intensity abnormalities then both algorithms threshodep_modt1 and threshodep_modt2 should be used to extract the abnormalities. Abnormality extraction using Region Splitting and Merging Segmentation algorithm with the function predicate is not up to the level. The extraction of the abnormalities using the Marker Controlled Watershed Segmentation is also not giving good results.

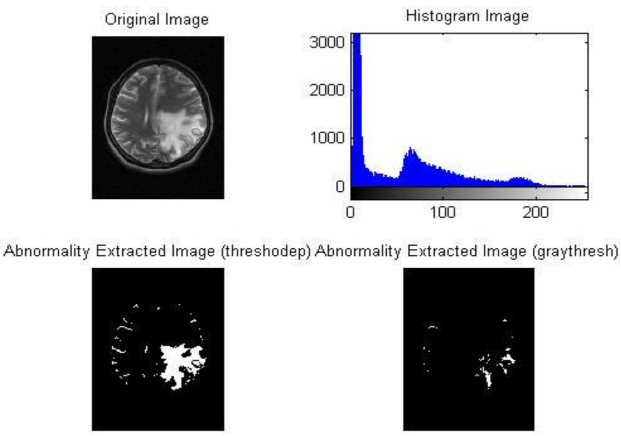

Fig 1: T2 Turbo Spin-echo Axial 13th Slice Image of a 30 year old patient with Venous Infarct. Extraction using regional growing segmentation algorithm with threshodep_modt2(J&K 2) and graythresh function. Function threshodep_modt2 gives good result and graythresh failed in this case.

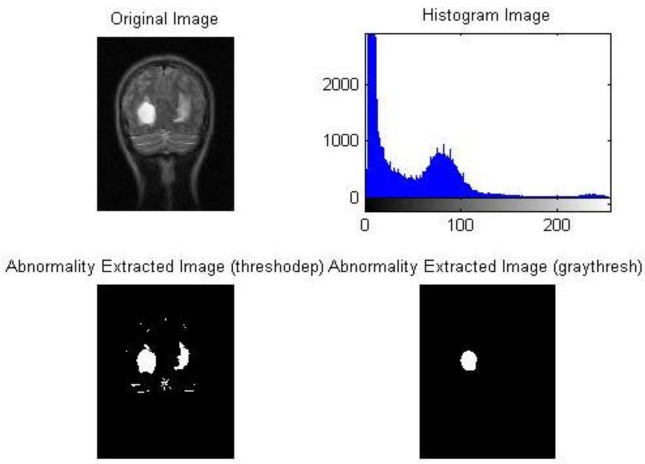

Fig 2: T2 Turbo Spin-echo Coronal 18th Slice Image of an 18 year old patient with hydrocephalus due to Colloid Cyst. Extraction using regional growing segmentation algorithm with threshodep_modt2(J&K 2) and graythresh function. Function threshodep_modt2 gives better result compared to graythresh.

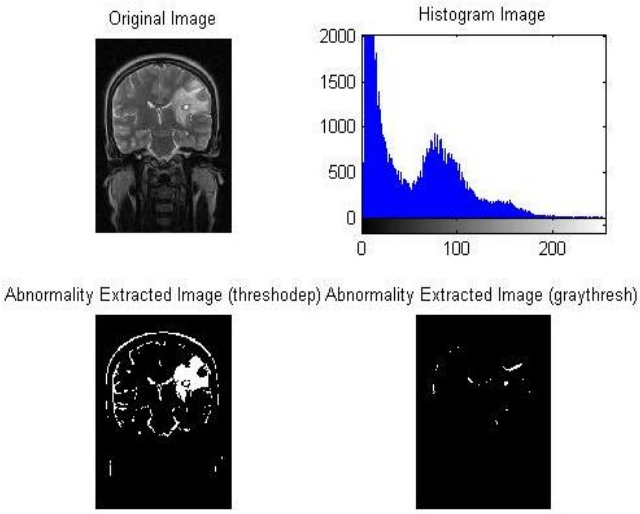

Fig 3: T2 Turbo Spin-echo Coronal 13 th Slice Image of a 46 year old patient with lesion with residual mass. Extraction using regional growing segmentation algorithm with threshodep_modt2 (J&K 2) and graythresh function. Function graythresh failed in this case.

Of the three methods studied and from many examples, it is found that using the Regional Growing Segmentation algorithms with author defined automatic seed point and threshold detection (J&K 1 and J&K 2 algorithms) are the best method for extracting the abnormalities of the MRI Images. This method automatically performs the abnormality extraction. So this method can be considering as the key factor for Intelligent Diagnostic Imaging system (IDIS) design.

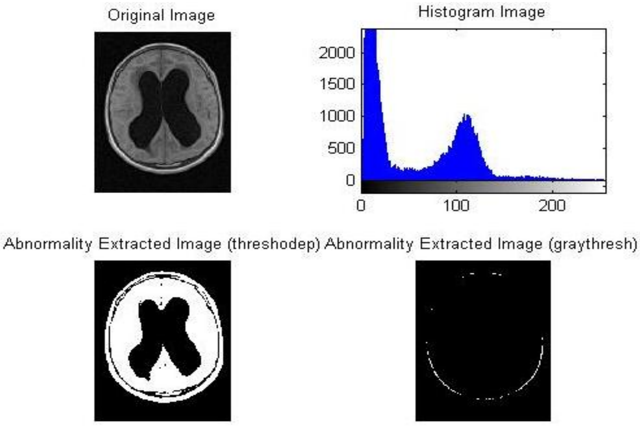

Fig 4: T1 Spin-echo Axial 12 th Slice Image of an 18 year old patient with hydrocephalus due to Colloid Cyst. Extraction using regional growing segmentation algorithm with threshodep_modt1(J&K 1) and graythresh function. Function graythresh failed in this case.

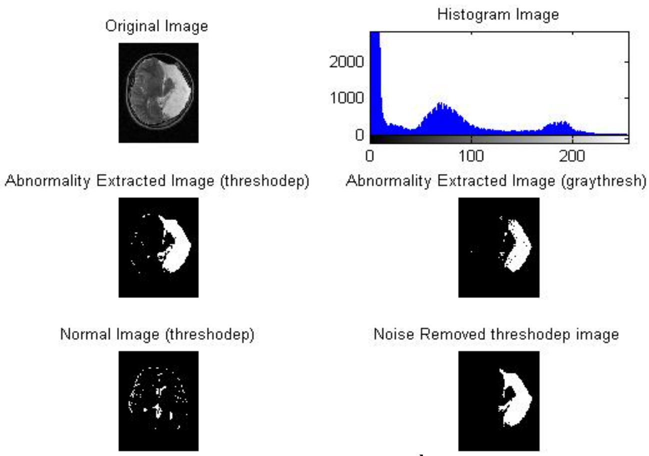

Fig 5: T2 Turbo-Spin-echo Axial 10 th Slice Image of a 16 year old patient with hemorrhage. Extraction using regional growing segmentation algorithm with threshodep_modt2(J&K 2) and graythresh function. Same slice image of a normal patient of same age group using regional growing segmentation algorithm with threshodep_modt2 Function . Noise removed image also shown.

All the abnormalities with clear intensity change can be detected by the algorithm. Benign Tumors, Malignant Tumors, Hydrocephalus and different type Lesions can be detected by the algorithm developed in this work. If the abnormality is hyper intense in nature then threshodep_modt2 function or algorithm for T2 is used for abnormality extraction. If the abnormality is hypo intense in nature then threshodep_modt1 function or algorithm for T1 is used for abnormality extraction. If the abnormality contain hyper intensity and hypo intensity region then both algorithm must used for abnormality extraction.

4. SENSITIVITY/ACCURACY TABLE OF ABNORMALITY EXTRACTION

Sensitivity/Accuracy Table of Abnormality Extraction is shown in table 1. The table compares the accuracy of author defined method with existing Otsu method for a few brain abnormalities. The accuracy of author defined method for individual slice is more than 98%, overall accuracy is well above 90% and sensitivity is above 95%. For T1, the existing method has completely failed. For T2, by using existing method the accuracy of individual slice is around 28% to 40% and overall accuracy is around 28% to 36%. The result is almost the same for other abnormalities also

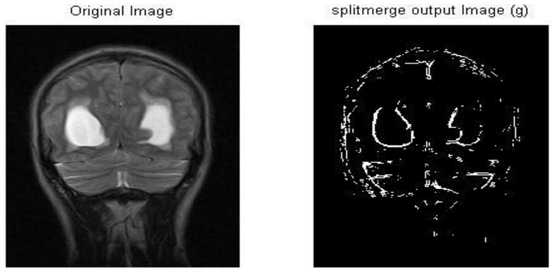

Fig 6: Extraction of the abnormalities of T2 Turbo Spin-echo Coronal 19th slice Image of an 18 year old patient with hydrocephalus due to Colloid Cyst using Regional Splitting and Merging Segmentation algorithm

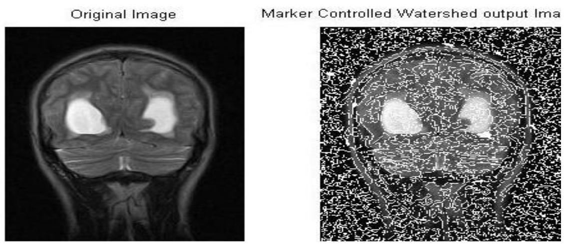

Fig 7: Extraction of the abnormalities of T2 Turbo Spin-echo Coronal 19th slice Image of an 18 year old patient with hydrocephalus due to Colloid Cyst using Marker Controlled Watershed Segmentation.

5. CONCLUSION

In absence of a well experienced physician, an Intelligent Diagnostic Imaging System (IDIS) can be used to diagnose the abnormalities. It provides the volumetric information of the abnormalities. It will help the surgeon to locate the abnormalities and help to understand the size and severity of the abnormality. The surgeon can plan the surgery in a better manner. This work is very helpful for the entire department especially the Radiology departments of Medical Colleges and Hospitals. No automatic diagnostic imaging system for brain is developed so far. Precise diagnosis is needed for brain surgery. Thus this is very important system. The designed IDIS will have good commercial applications. After having studied various developments that have taken place over the years in the area of medical imaging analysis, MRI techniques and GUI, We started with objectives of extraction of abnormalities in smaller scale and develop algorithms for abnormality extraction and diagnosis.

Table 1: Specificity/Sensitivity/Accuracy Table of Abnormality Extraction

S.L. No	Abnormality	No of Patients	Mode & Slice Mode	Total number of Abnormality slices	Abnormality extraction	Accuracy (Individual Slices)	Accuracy (overall)	Diagnosis Sensitivity
1	Hydroc-ephalus	3	T1 Axial	34	threshodep_modt1 (Author defined)	99%	93%	96%
					Graythresh (Otsu Method)	0%	0%	
			T2 Coronal	36	threshodep_modt2 (Author defined)	99%	92%	96%
					Graythresh (Otsu Method)	40%	30%	
2	Infract-ion	4	T1 Sagittal	62	threshodep_modt1 (Author defined)	99%	90%	96%
					Graythresh (Otsu Method)	0%	0%	
			T2 Axial	58	threshodep_modt2 (Author defined)	99%	91%	96%
					Graythresh (Otsu Method)	30%	28%	
3	Benign Tumors	1	T1 Coronal	12	threshodep_modt1 (Author defined)	99%	93%	96%
					Graythresh (Otsu Method)	0%	0%	
			T2 Coronal	12	threshodep_modt2 (Author defined)	99%	93%	96%
					Graythresh (Otsu Method)	40%	36%	

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