Algorithms to find the thresholds for the Abnormality Extraction of the MRI slice Images of a GUI based Intelligent Diagnostic Imaging System

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ABSTRACT

The purpose of abnormality extraction is to understand and identify the abnormality. It is very helpful to 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 consider as the key factor of the Intelligent Diagnostic Imaging System. Image segmentation is to partition 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. This paper describes the algorithm for threshold detection for abnormality extraction. Different algorithms are used for T1 and T2 MRI Images. This paper also explains the comparison of different segmentation techniques. 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.

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 the GUI is to see the result of an Intelligent Diagnostic Imaging system (IDIS) in an easy way. In GUI, the abnormalities are extracted and identified by comparing the patient's slice images with normal slice image. Abnormality recognition of abnormality extracted MRI image is a tedious task. First up all abnormalities are extracted from different slices of a patient and compared with normal slices. Then each abnormality images are compared with images in the abnormality image data set to identify and recognize the abnormalities. Finally GUI is developed which comprising of reading of the image slice by slice, extraction of the abnormality and display the result.

Medical image segmentation is generally difficult because often Noise-to-signal is 10% [1]. This is ten times Noise-to-signal of camera images. Medical images are often textured in complex ways and relatively poorly sampled. Many pixels contain more than one tissue type. This is called Partial Volume Effect [2]. Objects of interest have complex shapes and signs of clinical interest are subtle.

Image segmentation techniques that are based on the grey level histogram of an image can be based on thresholding or Clustering. It can easily understand that segmentation based on gray level thresholding by looking at the histogram of the low noise object/background image because there is a clear 'valley' between two peaks. We can define the grey level thresholding algorithm as follows: If the grey level of pixel p $<=$T then pixel p is an object pixel else, Pixel p is a background pixel. The threshold can be either Interactive threshold or Adaptive threshold or Minimisation method.

For greater histogram overlap, the pixel miss-classification is obviously greater. We could even quantify the probability of error in terms of the mean and standard deviations of the object and background histogram. Clustering tries to separate the histogram into two groups defined by two cluster centres c_1 and c_2. Grey level is classified according to the nearest cluster centre. A nearest neighbour clustering algorithm allows us perform a grey level segmentation using clustering. More general and widely used *K*-means clustering is a simple iterative algorithm which has known convergence properties.

2. INTELLIGENT DIAGNOSTIC IMAGING SYSTEM
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 [3]. This work is concerned with the development of GUI based Image processing tools that will automatically detect the abnormalities of the brain for the development of an Intelligent diagnostic Imaging System (IDIS). The proposed system diagnoses the abnormalities of brain at the time when MRI scan is taken.

2.1 Magnetic Resonant Imaging (MRI)
Protons of the hydrogen atom of human body act as a magnetic dipole. In the absence of an external magnetic field, magnetic

dipoles are randomly oriented, resulting to zero net magnetic fields. The introduction of an external magnetic field (B_0), forces the magnetic dipole to align in one of the two states: parallel (low energy) or anti-parallel (high energy). A small excess in the parallel direction results in a nonzero net magnetic field (M). For convenience, B_0 is along the z axis, so M is also along z axis. The transverse plane is perpendicular to the main field and contains x and y axis. For spin-echo imaging, 90-degree RF pulse is applied. M is flipped from the z axis to transverse plane. This transverse component of the M is entirely responsible for the MRI signal. M is returned to the equilibrium state by releasing energy called T1 relaxation (longitudinal). Immediately after the 90-degree RF pulse, the magnetic moments are located in the transverse plain [4]. Transverse (xy) magnetization suddenly decays constitute T2 relaxation (transverse). Fluid Attenuating Inversion Recovery (FLAIR) imaging technique is used to enhance the contrast [5].

MRI images are categorized in to mainly T1 and T2 images [6]. Pulse Sequences for MRI Imaging comprising of Spin-echo, Inversion recovery and Gradient-echo sequences. Spin-echo pulse sequences and Fluid Attenuating Inversion Recovery (FLAIR) sequences comes under T1 mode of scanning. Turbo Spin-echo sequences come under T2. Each type of imaging can be done either on axial, sagittal or coronal axes. Normal slice thickness is 5 mm for MRI scans. So for a person, there are about twenty images under each axial, coronal and sagittal axes and grand total of approximately two hundred images.

By using image processing methods, it is possible to find the size, shape and thickness of the abnormalities present in the image. Each type of abnormality has its own characteristic. By using these characteristic, the intelligent diagnostic imaging system can realize the abnormalities. T1 and T2 images of same slice are different in terms of intensity level. T1 imaging and T2 imaging are hypo-intensity (hypo) for calcification. T1 is hypo and T2 is hyper-intensity (hyper) for tissue growth. T1 is hypo and T2 is hyper for infarction. If the protein content is more, then T1 is hyper and T2 is hypo. For CSF, T1 is hypo and T2 is hyper [7]. So the same identification methodology cannot be applied for these images. A well advanced data base should be created for this intelligent imaging system.

2.2 Image processing
The image processing methods that will helps the development of Intelligent Diagnostic Imaging System are Filtering, Restoration, Segmentation, Reconstruction, Registration and Pattern Recognition [8]. Proper filtering methods can be adopted to remove the unwanted signal intensities and motion artifacts [9]. Normally MRI scan sequence lasts for half an hour to two hours. It is very difficult to make the scan without motion artifacts [10]. 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. Normal slice thickness is 5mm. Count the number of slices in axial, coronal and sagittal direction where the abnormalities are present. Then multiply the number of slices with the slice thickness in axial, coronal and sagittal direction will give

volumetric information of the abnormalities. By using the segmented abnormalities from each slice and slice thickness we can reconstruct the abnormalities. 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.

3. SEGMENTATION
3.1 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. 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. 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. Region based segmentation and segmentation using the watershed transform come under this category.

3.2 Region-Based Segmentation
3.2.1 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.

The MATLAB M function **regiongrow** is formed and used to do region segmentation [11] .The syntax for this function is

$$[G, NR, SI, TI] = \textbf{regiongrow}(F, S, T)$$

S can be an array (same size as F) with a 1 at the coordinates of every seed point and 0s elsewhere. S can also be a single seed value. Similarly, T can be an array (the same size as F) containing a threshold value for each pixel in F. T can also be a scalar, in which case it becomes a global threshold. On the output, G is the result of region growing, with each region labeled by a different integer. NR is the number of regions, SI is the final seed image used by the algorithm and TI is the image consisting of the pixels in F that satisfies the threshold test.

If the function is used for extraction of the abnormalities, it is found that TI is the most apt output Image. Input F is the slice image from which we have to extract the abnormalities. Input S is a scalar whose value is equal to the highest intensity level of the image. The value of the S is found by using author defined MATLAB M function **seedpo**. The syntax for this function is

$$S = \textbf{seedpo}(F)$$

Input T is a scalar, whose value is found by using *author defined MATLAB M function* **threshodep.** The syntax for this function is

T=**threshodep**(F,S)

3.2.2 Region Splitting and Merging

In Region Splitting and Merging, an image is initially subdivided into a set of arbitrary, disjointed regions [12]. Then the regions are merged and/or split in an attempt to satisfy the conditions stated by the predicate P. The MATLAB M function **splitmerge is** formed and used to do Region Splitting and Merging segmentation. The syntax for this function is

G=**splitmerge**(F, mindim, **@predicate**)

In **splitmerge**, Input F is the slice image from which we extract the abnormalities. mindim specifies the minimum dimension of the sub images (a positive integer of power of 2). **predicate is** an author defined function that sets FLAG to TRUE if intensities of the pixel in the region have a standard deviation that exceeds 9 and their mean intensity is between 0 and 255.

3.3 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 [13]. Over-segmentation can be controlled based on the concept of markers [14]. A marker is a connected component belonging to an image [15]. 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 [16]. 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;

3.4 Comparison of different Segmentation Methods

More than 200 selected cases of Brain MRI were studied at K. S. Hegde Medical College, Mangalore from March, 2008 to September, 2009. Out of which, around 20% of the cases are
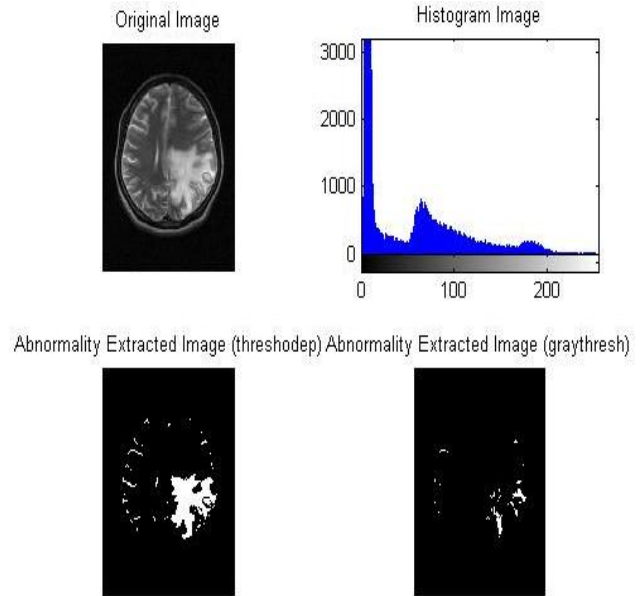

Fig 1: T2 Turbo Spin-echo Axial 13th Slice Image of a 30 year old patient with Venous Infarct. Extractions using regional growing segmentation algorithm with threshodep and graythresh function. Function threshodep gives good result. Function graythresh failed in this case.
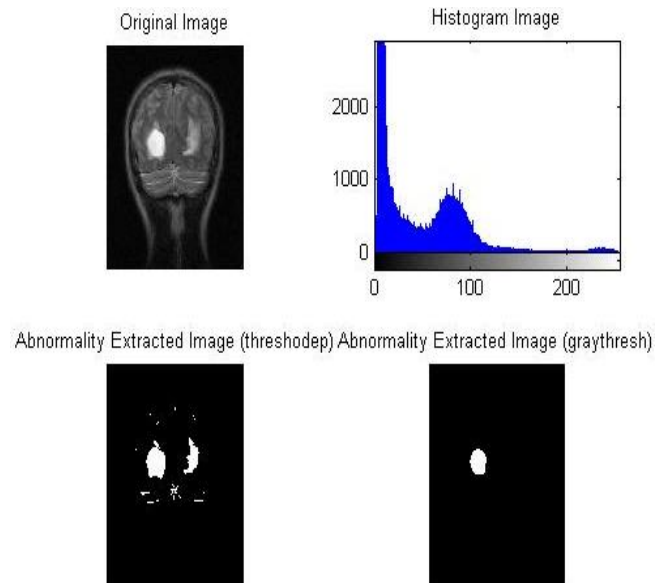

Fig 2: T2 Turbo Spin-echo Coronal 18th Slice Image of an 18 year old patient with hydrocephalus due to Colloid Cyst. Extractions using regional growing segmentation algorithm with threshodep and graythresh function. Function threshodep gives better result compared to graythresh.

Original Image   Histogram Image

Abnormality Extracted Image (threshodep)   Abnormality Extracted Image (graythresh)
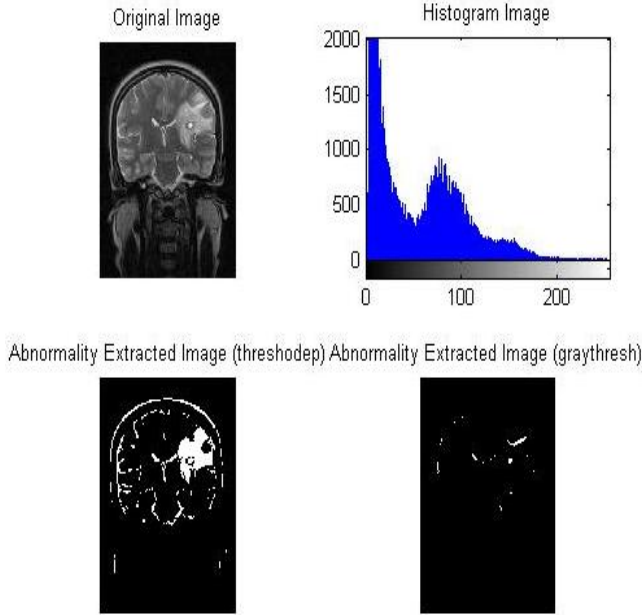
Fig 3: T2 Turbo Spin-echo Coronal 13 th Slice Image of a 46 year old patient with lesion with residual mass. Extractions using regional growing segmentation algorithm with threshodep and graythresh function. Function graythresh failed in this case.
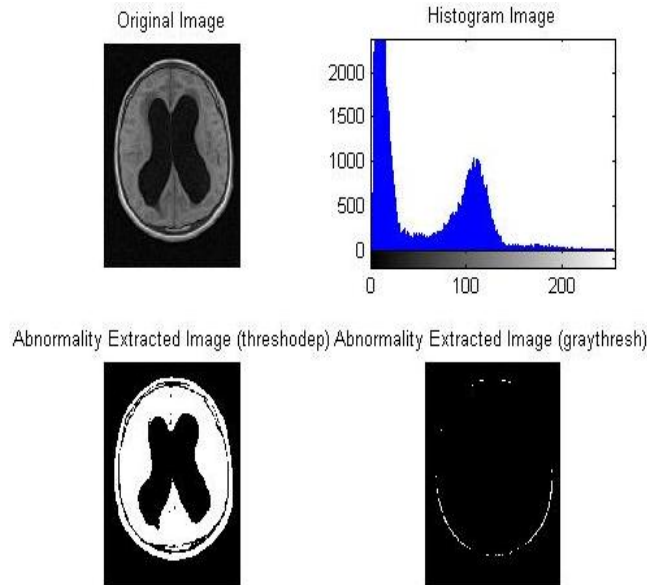

Original Image   Histogram Image

Abnormality Extracted Image (threshodep)   Abnormality Extracted Image (graythresh)

Fig 4: T1 Spin-echo Axial 12 th Slice Image of an 18 year old patient with hydrocephalus due to Colloid Cyst. Extractions using regional growing segmentation algorithm with threshodep and graythresh function. Function graythresh failed in this case.

Original Image   Histogram Image

Abnormality Extracted Image (threshodep)   Abnormality Extracted Image (graythresh)

Fig 5: T1 Spin-echo Axial 15 th Slice Image of an 18 year old patient with hydrocephalus due to Colloid Cyst. Extractions using regional growing segmentation algorithm with threshodep and graythresh function. Function graythresh failed in this case.
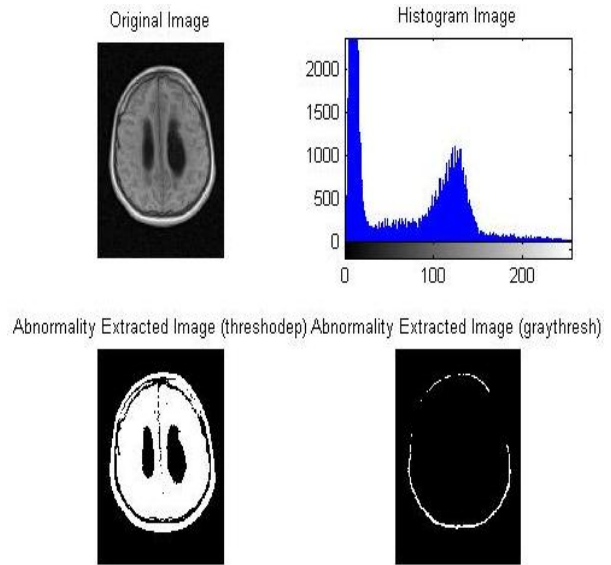
normal. Each case consists of more than 100 slice images. Some of the important images are segmented using above three methods for extracting the abnormalities. Threshold detection is done by using author defined threshodep function and graythresh MATLAB M function. In all cases threshodep function gives very good result and graythresh function failed in many cases. Figure 6 shows the extraction of the abnormalities using Regional Splitting and Merging Segmentation algorithm with the function predicate with FLAG is TRUE if the intensities of the pixel in REGION have a standard deviation that exceeds 9, and their mean intensity is between 0 and 255. The result is not up to the level. Figure 7 shows the extraction of the abnormalities using Marker Controlled Watershed Segmentation [17]. This method also does not give good result for abnormality extraction [18].

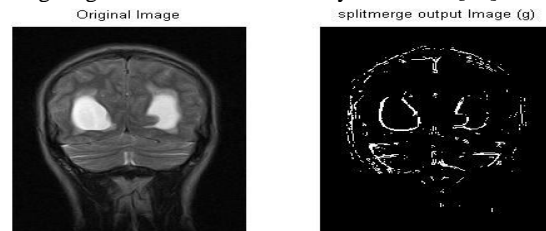

Original Image   splitmerge output Image (g)

Fig 6: Extractions of the abnormalities of T2 Turbo Spin-echo Coronal 19th slice Image of the same patient using Regional Splitting and Merging Segmentation algorithm.
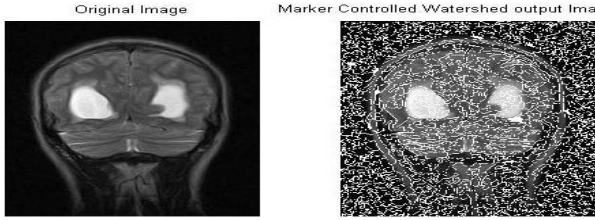
Fig 7: Extractions of the abnormalities of above figure using Marker Controlled Watershed Segmentation.

3.5 Result of Segmentation

Of the three methods studied, the Regional Growing Segmentation algorithm with automatic seed point and threshold detection is the best method for extracting the abnormalities of the MRI Images [19]. This method automatically performs the abnormality extraction. So this method can be considering as key factor for Intelligent Diagnostic Imaging system (IDIS) design. The author defined threshodep function is best suited for T2 Turbo Spin-echo and T1 spin-echo images. If the image contains hypo and hyper intensity abnormalities, then threshodep for T1 and T2 functions should be used to extract the abnormalities.

4. THRESHOLD DETECTION ALGORITHM

MRI images can be classified mainly in to T1 and T2 images [20]. The algorithm used for T1 and T2 images are different and is developed by the author. By using this algorithm more precise threshold can be found. Thresholdp user defined function uses these algorithms. Compared to MATLAB graythresh function, thresholdp detects abnormalities of variety of slices. Around 50% of cases graythresh failed but thresholdp failed only in 10% of cases.

In *threshodep*, T 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 [21]. Finding the valley point is a difficult task [22]. First, we have to find the maxima of each subsection. For that we used a moving window of size 10 and it is moved from high intensity level to the low intensity level for T2 and low intensity to high intensity for T1 in an overlapped manner of 5 intensity level and finds the maxima (pixel). For T2, the maxima values are analyzed from high intensity side to the low intensity side. For T1 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.

4.1 Threshold Detection algorithm for T1

The first hill point can be found by the following method. If three consecutive maxima are identical in low intensity side, then that maxima is considered as hill point or if two consecutive maxima values are identical and left and right maxima from the identical maxima are decreasing in magnitude in low intensity side then the identical maxima whose intensity level are same can be consider as a hill point. It can be found by using the following MATLAB expressions [23].

```
for j=47:-1:3
if((M(j)==M(j-1))&(M(j)==M(j-2)))|
((M(j)==M(j-1))&((((M(j-1)-M(j-2))>0)|((M(j-
2)-M(j-3))>0))&(((M(j-1)-M(j-2))>=0)|((M(j-
```

```
2)-M(j-3))>=0))))&((((M(j)-
M(j+1))>0)|((M(j+1)-M(j+2))>0))&(((M(j)-
M(j+1))>=0)|((M(j+1)-M(j+2))>=0)))
                e=j-3;
                h1=M(j);
                k1=I(j);
break;
end;
end;
```

Where M(j)s are the maxima values. h1 is the first hill point. k1 is the corresponding intensity value.

The candidates for the second hill point can be determined by the following method.

```
for q=e:-1:3
        if  (M(q)==M(q-1))&((((M(q)-
M(q+1))>0)|((M(q+1)-M(q+2))>0))&(((M(q)-
M(q+1))>=0)|((M(q+1)-M(q+2))>=0)))&((((M(q-
1)-M(q-2))>0)|((M(q-2)-M(q-3))>0))&(((M(q-
1)-M(q-2))>=0)|((M(q-2)-M(q-3))>=0)))
                h=q-2;
                h2=M(q);
                k2=I(q);
                break;
            end;
end;
```

Where M(q)s are the maxima values. h2 is the candidate for the second hill point. k2 is the corresponding intensity value. Similarly the second and third candidate can be found. From the candidates, if the second and third candidates satisfy the following condition the third candidate is considered as second hill point.

```
if ((T3>T2)|(abs(T3-T2)<500))&((k1-k3)<175)
        Th=T3;
        kh=k3;
```

Where T3 and T2 are the third and second candidate and k1 and k3 are the intensity level of first hill point and third candidate. Th is the second hill point.kh is the corresponding intensity level.

The valley point can be found by the following method. The intensity region between first and second hill point is divided into two to three regions. Find the minima of each region. If the absolute difference between each set of minima lie within the predefined threshold, then minima towards the lowest intensity side is considered as the valley point. If minma2 is the minima of the middle region and minima3 is the minima of region near the high intensity side. If the absolute difference between minima2 and minima3 lie within the predefined threshold, then minima2 is considered as valley point otherwise minima3 is considered as valley point.

After finding the valley point, the intensity level of the valley point is subtracted from 255 to obtain the value of Threshold that is used to segment (extract) the abnormality.

4.2 Threshold Detection algorithm for T2

Threshold detection of T2 image can be done in exactly opposite way that is done in T1 threshold detection. Here we have to move from high intensity side to low intensity side.
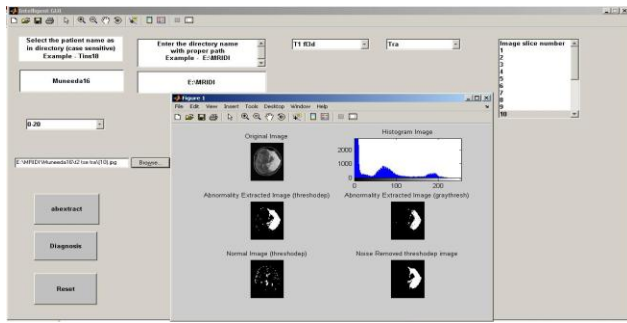
5. GUI DEVELOPMENT

Fig 8: GUI after the run command. GUI with proper selection of patient and process, showing the abnormality extraction.

In the GUI for IDIS, abextract pushbutton callback comprising of the Regional Growing Segmentation algorithm with automatic seed point and threshold detection is used for extracting the abnormalities of the MRI Images. Threshold detection is done by using author defined threshodep function and graythresh MATLAB M function. The patient selection can be done by using the pop-up menu. The callback for the pop-up menu is linked with the patients' data base [24]. In order to see the slice image before processing, imageread pushbutton can be used [25]. Comparison of author defined threshodep function and graythresh MATLAB M function can also be done on GUI. The GUI appearance can be still modified by incorporating more objects [26].

6. CONCLUSION

With GUI the IDIS is more user- friendly and with this system one can easily understand the abnormality of the brain Image. Slice Image abnormality can be integrated to get a volumetric structure that can be used for correct diagnostic and surgery. The same tool can be extended to other sort of biomedical Images.

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