Graphical User Interface Based Computer Aided Diagnosis Tool of Human Brain Tumor Segmentation Through MRI and Validation

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Abstract
An important prerequisite for clinical analysis and treatment is a stage for medical image handling strategy that is more adaptable and accurate. A multifunctional graphical user interface (GUI) tool for computer aided diagnosis (CAD) that performs interactive image processing of brain tumor MRI images is presented in the proposed work. The proposed technique consists of different stages such as analysis, segmentation, Evaluation, Quantification, and Validation. The various functions implemented in the tool such as histogram equalization, Thresholding, image smoothing and clustering based segmentation, tumor detection along with some basic functions are explained in detail. In addition to this, the performance measures defined as probability random index (PRI), global consistency error (GCE), structural similarity (SSIM), variation of information (VOI) integrated in GUI-CAD is explained. Building effective Computer-Aided Detection and Diagnosis (CAD) systems involves the combination of running experiments, image mark up, security, analysis, evaluation, and validation in order to capture and evaluate medical images effectively. The system design enables radiologists to upload their feature sets and quickly compare the effectiveness of their methods against other stored feature sets.

Keywords: Medical imaging, Magnetic resonance images, Segmentation, Intelligent computer-aided diagnosis system, Human brain tumors.

Introduction
In recent times computer aided diagnosis (CAD) has developed as one of the essential and significant exploration subjects in medical imaging and demonstrative radiology. The fundamental idea of CAD is to give a computer output as a second opinion to help radiologists’ image interpretation by enhancing exactness and consistency of radiological diagnosis furthermore by diminishing the image perusing time. CAD has generally been defined by diagnosis made by a physician who takes into account the computer output based on quantitative analysis of radiological images. The goal of CAD is to improve the quality and productivity of radiologists. Therefore for advancement of a successful CAD scheme it is essential to create computer algorithm, as well as to research how valuable the computer output would be for radiologists in their diagnosis, how to evaluate the benefits of the computer output for radiologists, and how to expand the effect of the computer output on their diagnoses. The innovative work of CAD have included a collaboration by investigators with various foundations, for example, physicists, radiologists, computer researchers, specialists, analysts and psychologists with satisfaction on potential clinical application. The general approach for CAD is to find the location of a tumor and also determine as an estimate of the probability of a disease; these correspond to CAD for detection of a tumor and CAD for differential diagnosis. The essential technology involved in CAD schemes are: 1) image processing for detection and extraction of abnormalities; 2) quantization of image features for candidates of abnormalities; 3) data processing for classification of image features between normal and abnormal (or benign and malignant); 4) quantitative evaluation and retrieval of images and 5) observer performance studies. With automated computer analysis, the execution level of the computer output is required to be high. For instance, if the sensitivity for detection of tumors by computer would be lower than the average sensitivity of doctors, it will be hard to legitimize the utilization of automated computerized determination. This is because of the patients in most advanced nations would not be able to accept a lower level of diagnostic results by computer than the average level achievable by physicians. Indeed, despite the fact that CAD has been utilized generally for location of cerebrum tumors highs specificity and sensitivity by computer are required for implementing automated computer diagnosis. Further examination of image segmentation results may also provide an objective quantification of the significant properties of tumors, for example, data identified with size or shape, metabolic-related data, and investigation of the molecular changes associating a pathological behaviour to a treatment result. Segmentation of brain tumors is a
troublesome task, because of the complex anatomy and a few issues that are characteristic to the way of the image. The heterogeneous and diffuse manifestation of this pathology in medical images complicates the execution of computational strategies ready to manage this incredible variability of examples. Additionally, all image modalities present confinements and artifacts that should be addressed by segmentation strategies. The purpose of this paper is to define a multifunctional graphical user interface (GUI) tool for computer aided diagnosis (CAD) that performs interactive image processing of brain tumor MRI images.

Related Work
The success of CAD would require large efforts on many aspects of CAD research such as development of computerized schemes for many different types of lesions in many different modalities, observer performance studies, clinical trials, and commercialization. This section deals with the works related to the CAD based brain tumor detection and segmentation in medical image.

J.selva kumar, A.lakshimi et.al [1] has proposed Brain tumor segmentation and its area calculation in brain MR images using K-mean clustering and Fuzzy C-mean algorithm. This paper deals with the implementation of Simple Algorithm for detection of range and shape of tumor in brain MR images by using a computer aided method for segmentation (detection) of brain tumor.

Vida harati, Rasoul khayati et.al[2], has developed a method for Fully automated tumor segmentation based on improved fuzzy connectedness algorithm in brain MR images. This algorithm is independent of the tumor type in terms of its pixels intensity. Tumor segmentation evaluation results based on similarity criteria (similarity index (SI), overlap fraction (OF), and extra fraction (EF) are 92.89%, 91.75%, and 3.95%, respectively) indicate a higher performance of the proposed approach compared to the conventional methods, especially in MR images, in tumor regions with low contrast.

Reza farjan, Hemanth A.parmar et.al,[3] had developed an approach for computer-aided detection (CAD) of small brain metastases in post-Gd T1-weighted magnetic resonance imaging (MRI). In this paper the Effects of image factors of noise and intensity variation on the performance of the CAD system were investigated. A nodule enhancement strategy to improve sensitivity of the system and a set of criteria based upon the size, shape and brightness of lesions were used to reduce false positives.

Nidhi Gupta and pritee khanna[4] has developed an algorithm for “A fast and efficient computer aided diagnostic system to detect tumor from brain magnetic resonance imaging”. In this work, a simple and efficient CAD computer-aided diagnostic system is proposed for tumor detection from brain magnetic resonance imaging MRI. The proposed technique is well adaptive and fast, and it is compared with well-known existing techniques, like k-means, fuzzy c-means, etc.

J.Vijay and J.Subhashini [5] had developed an efficient brain tumor detection methodology using K-means algorithm. This paper describes an efficient method for automatic brain tumor segmentation for the extraction of tumor tissues from MR images. In this method segmentation is established out using K-means clustering algorithm for improved performance. This enhances the tumor boundaries more and is very prompt when compared to many other clustering algorithms. The proposed technique produces appreciative results.

Vijay kishore [6] has developed a Multi Functional Interactive Image processing tool for Lung CT images where the tool is capable of displaying information about the loaded image of the selected format read and save images from and to the workspace and evaluation of the segmentation approaches.

Proposed System
Development of Graphical User Interface Based Computer Aided Diagnosis (GUI-CAD) Tool
A multifunctional GUI-CAD tool that performs interactive image processing of medical images is developed. The tool is designed using MATLAB and performs multiple image processing functions for processing of images in different formats. Upon execution of the tool the start-up view of the GUI-CAD is displayed which gives information about the tool, GUI-CAD tool window Figure.1 with seven broad tool bar functions inputs, processing, analysis, segmentation, quantification, evaluate, validation, and Measures which includes different image processing functional processing tools.

The different functional tools developed and integrated in the GUI-CAD tool that perform interactive image processing of medical images are Loaded image of different formats (tiff, jpg, DICOM etc, Load single and series DICOM(Digital Imaging and Communication in Medicine).

Objectives
➢ To design a system having simple and effective user interface to have seamless integration with the decision making process.
➢ To provide a reliable second opinion to aid in the decision making process.
➢ To reduce the computation complexity of algorithms to make them more suitable for real-time applications.
➢ To provide seamless integration into the workflow.
➢ To provide an quantification based on the tumor area
➢ To improve the diagnostic accuracy.
➢ To increase the efficiency in Identification, Interpretation and Validation of brain tumor.

Description of GUI CAD Tool Functions
Load Image:
Using the load image tool bar function images of different formats like tiff, jpg, DICOM can be read by the tool as input images for processing. In addition to this single or a series of DICOM images can be read and displayed by the tool. After reading DICOM series images, the slices can be flipped, and three different views viz: Transverse, Coronal, Sagittal can be provided. The load image function also has the option of saving the image to the current workspace, reading from current workspace and can also provide information about the image details like file mod date, format, format version, file name, width, height, bit depth, color type, image type, study
time, study date, series date, content date, series time, modality, patient name, software version, samples per pixels, manufacturer, institution name, rows-columns, bits allocated, bits stored, series number, high bit, pixel representation, smallest image pixel value, pixel padding value, window centre, window width etc., if recorded while image acquisition. Figure 1 & 2 shows the CAD tool with functions and GUI for reading image.

**Figure 1:** CAD tool window with tool bar functions.

**Figure 2:** GUI for reading a medical image

**Pixval:**
This function can determine the intensity value of the pixel on the image (single or slice of series DICOM image) at any location on the image. Selecting this, observer can know the value of the intensity at any pixel location. Abnormality can be identified depending on whether the intensity value is attenuated at a particular location or locations. By just moving the cursor on the image, the coordinates and the intensity value at that point are displayed at the bottom of the window as shown in Figure 3 for a MRI image. The value $A(i,j)$ gives the value of a particular pixel stored at the row number $i$ and column number $j$. The tool is capable to display information about the pixel value and location of individual pixels in an image in the bottom left area of the tool. The pixel value and the location information represent the pixel below the existing location of the pointer. As the pointer is moved over the image the image viewer updates this information, Figure 3 shows the GUI for the pixel value.

**Histogram:**
Histogram gives information about the probability of occurrence of a particular gray level value in the image. The histogram appears as a graph viewing the brightness on the horizontal axis from 0 to 255 for 8 bit intensity scale and on the vertical axis the number of pixels. It is a design of gray level values versus the number of pixels at that value. For colour images the histogram are computed as one for the each component (RGB), using this graph the user capable to see immediately the details such as whether the image is essentially high or low contrast, it also provides clues about what contrast enhancement would be applied to make the image subjectively satisfying to an observer. In medical images the histogram with two major peaks called bimodal can imply an object that is in contrast with the background and narrow histogram implies a low contrast image. Histograms can be used for image enhancement and for selecting the threshold that can be used for image segmentation. The histogram plot of MRI image are shown in Figure 4.

**Figure 3:** GUI for showing the pixel value in medical image

**Figure 4:** GUI for showing the Histogram value in medical image
**Intensity Profiles:**

Another function that GUI can perform is to generate profiles which are one dimensional plots indicating the variations of the intensities along a selected horizontal and vertical lines on the image. The intensity profile of an image is the set of intensity value taken from frequently spaced points along a line segment or multiline path in an image. The user has the option to select for horizontal and vertical profiles of the intensities by simply clicking on the image line either vertical (column) or horizontal (row). This helps the user to know and understand the intensity variations at some particular line horizontal and vertical individually. These plots of the intensity profiles can be obtained for DICOM image. The improvise function calculates and plots the intensity values along a line segment or a multiline path in an image. The function uses the nearest neighbour interpolation, and works best with gray scale and color images. The coordinates of the line segment can be supplied as input arguments or define the desired path using a mouse. For a single line segment, improfile plots the intensity values in a two-dimensional view. For a multiline path, improfile plots the intensity values in a three-dimensional view. Figure 5&6 demonstrates the GUI for knowing Horizontal and vertical profiles in MRI Image. The intensity profiles indicate the variations of intensities along horizontal and vertical lines on the image.

**View Current Slice:**

This function will enable the user to view the current slice loaded in image tool window. The Image Tool is an image display and examination tool that presents an incorporated environment for displaying images and performing common image processing tasks. The Image Tool provide admission to numerous other functions like display the range of intensity values and also the pixel information on the window, zoom, pan, crop image, pixel region, measure distance, image information, adjust contrast, and choose color maps as shown in Figure.7

Crop image is a function which the user can select a particular region on the view current slice window and crop that particular region in another window shown in figure 8. The user can create new image from part of the original image. In this the pixel values along with the coordinates can be displayed and also the cropped region can zoomed in and out.

Pixel region is another function integrated in view current slice. This function allows the users to select a particular region on the image and to know the pixel distribution or neighbourhood extension of the pixels in that particular region in separate window, along with the pixel values. This function enables the user to determine the location and intensity value of the pixel by moving the cursor and also to determine the intensity values of the group of the pixels by selecting the region using pixel region rectangle. The view of pixel region is shown in Figure.9

Measure distance is another function of view current slice that allows the users to find the Euclidean distance between the single selected points or on multiple locations selected on the image Figure.10 The tool specifies the distance in data units determined by the X data and Y data properties, which is pixels, by default.
Adjust contrast is a function which displays the data range, window maximum and minimum intensity values along with width and center, and scale display range with match data range and eliminate outliers percentage. The intensity values can be adjusted by changing the histogram plot or drag the mouse over image or simply by clicking the adjust data button. This particular function is useful to adjust the intensity ranges of the image and to vary the contrast to recognize certain details as per the requirement. The function view is shown in Figure 11.

Colormaps is another function integrated in the view current slice window. This particular function will link all the seventeen MATLAB colormap functions that can be used to view the image (Figure 12).

Zoom tool enables zooming in and zooming out, to get a closer look by enlarging or shrinking the image to view the whole image in context. Overview tool for determining what part of the image is currently visible in the Image Tool and changing this view. If an image is big or viewed at a large enlargement, the Image Tool displays only a portion of the entire image, including scroll bars to allow routing around the image. Overview tool is used to determine which part of the image is currently visible. A rectangle called detail rectangle shows which part on the image is currently visible in Image Tool and the portion of visible image part can be changed by moving the detail rectangle over the image (Figure 13).

Smooth Volume
The aim of image enhancement is to improve the perception or interpretability of information present in the image for human viewers or to provide better input data for other automated image processing techniques [103, 104]. The aim of image smoothing is to either reduce noise within an image or to produce a less pixilated image. It is also used for noise reduction and for blurring. In some applications blurring an image is a pre-processing step to fill gaps in lines or curves and to remove tiny detail from an image prior to object extraction. Noise reduction can be achieved by introducing blurring with a linear or nonlinear filtering method Figure 14 shows the display for smoothing an image.

Thresholding
Thresholding is a technique that produces regions having similar intensities. By proper selection of the threshold value, thresholding can be used for establishing boundaries that contain solid objects or regions. In this, two options are provided, one is manual thresholding where the user can select the threshold value of choice and the second is auto thresholding which uses an algorithm based on specific criteria, finding initial threshold and computing new threshold by taking the average of all pixel values in the region and repeating the process. The displays of manual Thresholding of both single DICOM image is shown in Figure 15.

Tool bar Menu: Segmentation
This method is used as a tool for proposed CAD system for automatic detection and quantification of brain tumor from DICOM-MRI scan image and is integrated in the GUI-CAD tool.
K-Means Clustering

K-Means calculation is an unsupervised algorithm that characterizes the input information into various classes in view of their inherent separation from one another. The calculation accepts that the information highlights frame a vector space and tries to discover normal grouping in them. The points are clustered around centroids. A cluster is a gathering of objects which are similar between them and are not at all like the objects having a place with different groups. Clustering is an unsupervised learning system which manages discovering a structure in a gathering of unlabeled information. K-means clustering is an algorithm to gathering objects in view of attributes/features into k number of gatherings where k is a positive integer. The gathering (clustering) is finished by minimizing the Euclidean separation between the information and the comparing cluster centroid.

For a given image, compute the cluster means m

\[
M_k = \frac{\sum_{i \in C(k)} x_i}{|C(k)|}, k=1, \ldots, K. 
\]

(1)

Calculate the distance between the cluster center to each pixel

\[
D(i) = \arg \min_j \| x_i - M_j \|, i=1, \ldots, N
\]

(2)

1. In the image let D be the data points.
2. Partition the data points into k equal sets.
3. Take the middle point in each set as initial centroid.
4. Calculate the distance between each data point (1 ≤ i ≤ n) to all initial centroids (1 ≤ j ≤ k).
5. For each data point dt, find the closest centroid cj and assign dt to cluster j.
7. Set Neare[i] = d(dt, cj).
8. For each cluster (1 ≤ j ≤ k), recalculate the centroids.
9. For each data point dl, (i) compute its distance from the centroid of the present nearest cluster. (ii) The data point stays in the same cluster if this distance is less than or equal to the present nearest distance, otherwise compute the distance (dl, cj) for every centroid (1 ≤ j ≤ k).
10. Repeat from steps 5 to 9 until convergence is m.

Validation and Results

The sequence followed for validating the developed tool is

- The images obtained from two sources are input to the GUI-CAD tool separately.
- The tool performs required operations and produces output image views that contain segmented Region of Interest of brain tumor, quantification, evaluate based on PRI (Probabilistic Rand Index), VOI (variation of information) &GCE (global consistency error), Structural similarity index(ssim). These output image views for various Brain MRI images are shown to the expert radiologists and are asked to classify.
- Based on the segmented Region of Interest, quantification and evaluation the clinical experts classified the brain tumor as True Positive, False Positive, True Negative, and False Negative. The experts’ classifications are shown in Table. I

<table>
<thead>
<tr>
<th>Clinical Expert</th>
<th>Image Data Base</th>
<th>True Positive</th>
<th>False Positive</th>
<th>True Negative</th>
<th>False Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Image Set 1</td>
<td>137</td>
<td>13</td>
<td>108</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Image Set 2</td>
<td>135</td>
<td>15</td>
<td>113</td>
<td>7</td>
</tr>
</tbody>
</table>

An add-on User Interface for performance measure (Figure.17&18) is developed and integrated into the GUI-CAD tool for radiological diagnosis. The tool also saves the
parameters and their plots in Microsoft Excel sheet for reference and record shown in Figure 19. This tool computes radiological parameter values, and plot the graphs of Accuracy, Error, Sensitivity, Specificity, Positive predictive value (PPV), Negative predictive value (NPV), False detection rate (FDR), Matthews correlation coefficient (MCC), False prediction rate, False negative rate. Prediction conditioned fallout, Prediction conditioned miss, Rate of positive prediction, Rate of negative prediction, Odds ratio, Likelihood ratio positive, Likelihood ratio negative, Prevalence, Pretest odd, Posttest odds of outcome for given positive test results, Posttest odds of outcome for given negative test results. These plots are used to estimate the efficiency of the work in segmenting the tumor, quantification and validation.

**Figure 16:** GUI for K-Means segmentation of brain MRI image

**Figure 17:** Validation measures of the proposed segmentation

**Figure 18:** Performance measure tool for CAD system

**Figure 19:** User Interface performance measure tool for CAD system: Results Excel sheet of various performance assessment parameters and sheets of individual parameters

**Experimental result analysis and discussions**

The performance measures used to analyze the execution are PRI (Probabilistic Rand Index), VOI (variation of information) & GCE (global consistency error). PRI assesses the pair wise connections between pixels of divided result and numerous ground-truth divisions and takes values in the range (0, 1). Hence higher PRI esteem shows a superior match between the sectioned result and the ground-truth information. VoI, GCE are error measures that have to be reduced by the good segmentation algorithm.

**Probability Rand Index (RI)**

The Rand measure is a measure of the similitude between two data clusters.

\[ R = \frac{(a+b)}{(a+b+c+d)} = \frac{(a+b)}{(n^2/2)} \]  

**Variation of Information (VOI)**

The Variation of Information (VOI) metric characterizes the distance between two segmentations as the average conditional entropy of one segmentation given the other, and in this manner measures the measure of randomness in one segmentation which can't be clarified by the other.

At that point the variety of information between two clustering is:

\[ V_I(X; Y) = H(X) + H(Y) - 2I(X, Y) \]  

**Global Consistency Error (GCE)**

The Global Consistency Error (GCE) measures the degree to which one segmentation can be seen as a refinement of the other.

\[ \tau = \sum_{j=1}^{N_c} \sum_{i=1}^{N_c} 1 \| X^{(i)} - C_j \|^2 \text{ where } \| X^{(i)} - C_j \|^2 \]  

**Structural similarity**

Structural Similarity Index (SSIM) is a method for measuring the similarity between two images. The SSIM is measured between two windows X and Y of common size N*N on image using Eq. (3).

\[ SSIM(x, y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \]

The experiment is conducted over the Brain tumor MRI images using the, K-means segmentation and their outcomes appeared in Fig.16 with required measurable parameters and their outcomes are exhibited in Table 2.
Table 2: Performance evaluation

<table>
<thead>
<tr>
<th>METHODS</th>
<th>PRI</th>
<th>VOI</th>
<th>GCE</th>
<th>PSNR</th>
<th>SSIM</th>
<th>Tumor area (sq. mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-Means</td>
<td>0.9796</td>
<td>0.126</td>
<td>0.01663</td>
<td>46.88</td>
<td>0.9568</td>
<td>0.0388</td>
</tr>
</tbody>
</table>

Conclusion

The results and observations show that the research work is successful in segmenting the brain tumor from the MRI images based on the proposed work. The tool is developed in MATLAB and is user-friendly. This research work provided various functions like reading a medical image of different format, thresholding, different color map windows, histogram, horizontal and vertical profiles of intensity variations along a time, and determine the intensity of a selected pixel on the image, segmentation based on clustering approach. The resultant images of the GUI-CAD tool provide a second opinion to the radiologists in discriminating brain tumors. The effectiveness of the CAD tool is analysed using a variety of performance assessment parameters. The quantification helps in abstracting clinical opinion to provide a better diagnosis and prognosis. The performance measures of the tool indicate the suitability and reliability of the tool in providing an authenticated secondary opinion. The research work has the potential to serve as an effective tool in managing and early diagnosis of brain tumors.

References


