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Brain Tumor Segmentation based on Rough Set Theory for MR Images with Cellular Automata Approach

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Abstract*: Prediction of brain tumour and analysis is very critical in medical image processing since the treatment is based on radio surgery. Classifying the enhanced and necrotic cells is very essential in clinical radio surgeries, where in a radio oncology expert predicts the tumors manually for contrast enhanced T1-MR images. Prediction best works with cellular automata (CA) iterative algorithm by deriving transition rules from the tumour properties with adaptive method. Rough set theory with attribute reduction algorithm is used for classifying the enhanced and necrotic cells. In this work a semi interactive prediction algorithm is used with CA and Rough set theory for incomplete data prediction in medical images. Semi interactive algorithms require less manual intervention with high computation speed.

Index Terms*: Brain tumor prediction, Rough Set Algorithm, Cellular automata, magnetic resonance imaging (MRI), radio surgery, enhanced cells, necrotic cells, reduct.

I. INTRODUCTION

The abnormal growth and accumulation of extra cells in the brain which disturb the normal functioning of the brain is called a brain tumour. There are many kinds of brain tumours like benign tumours which do not enclose cancerous cells, malignant tumours which enclose cancerous cells, and a primary brain tumour which initiates from brain cells or nerve cells or glands or from the meninges, a secondary tumour which initiates from one part of the body and reach to brain. Along with the type and grade of the tumour the exact location and size of the tumour is also very important for the treatment and diagnosis. MRI gives the detailed images of the brain. MRI uses a powerful magnetic field, radio frequency pulses to produce detailed pictures of organs, soft tissues, bone and virtually all other internal body structures. It does not utilize ionizing radiation (x-rays) which makes it better option than CT scan.MRI generates images by changing signal intensities for different tissues. There are different types of MRI images.T1 weighted images are generated when the machine is programmed to the longitudinal movement of protons. These give the normal anatomical details .T2 weighted images are generated when the machine is programmed to the transverse movement of protons and are used to look at pathology. In many cases diagnosis for brain tumour is based on radio surgery wherein finding the exact border that separates the enhanced cells from necrotic cells is very important. To outline the exact border a semi interactive segmentation framework is developed with cellular automata iterative algorithm along with the rough set theory

II. METHODOLOGY

Semi interactive prediction algorithms

Semi interactive segmentation methods are more popular compared to the manual and automatic segmentation methods since the manual processes are very difficult and the results are not accurate and we cannot rely on automatic segmentation processes because of the different anatomical structures of the brain. There are different types of semi interactive segmentation methods.

Region growing segmentation: The basic principle of region growing segmentation is the pixels which are having similar characteristics are grouped together. The process starts by selecting a single seed pixels and checking for all the neighbours' characteristics, if the neighbours have same characteristics as the chosen seed pixels the new pixels are added to the pixels and the region grows. Choosing the initial seed pixels and the homogeneity criteria are very important in region growing methods. The homogeneity criteria is derived based on the general characteristics of an image such as mean, variance, color,texture,shape ,size etc

Boundary based segmentation: Boundary based segmentation is used to locate or outline the exact boundary of an image or a object which is not achieved with the region based method. The important characteristics of an image that gives information on the edge or border is the change in intensities. Locating the edge of the tumour in an MRI brain image is very important in radio surgeries. In this approach a local derivative of an image is computed which is also called gradient operators. The magnitude of the first derivative is used to find the edge in a image.

Using a method will not give accurate results, combination of the region based and boundary based can be used for the best extraction of the tumour from the MRI image.

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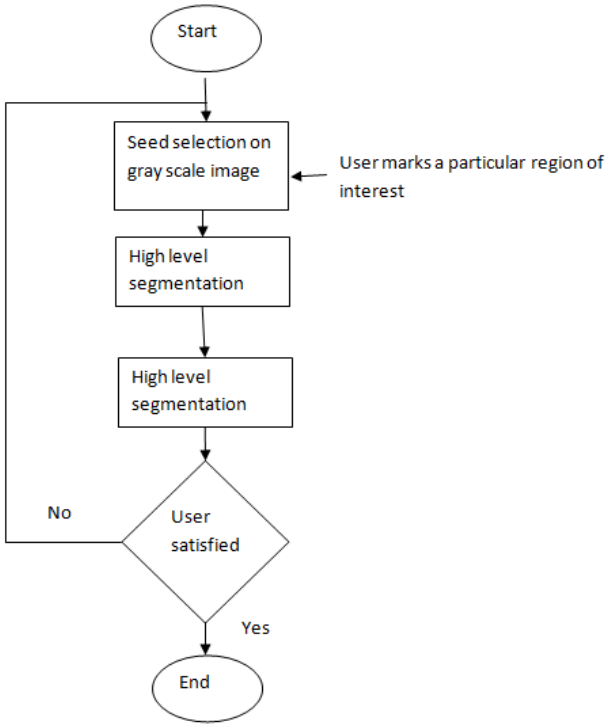

Figure 1 Flowchart of semi interactive prediction

When the user marks a particular region of interest on the image, the foreground seeds or tumour seeds are obtained by cropping the line by a certain percentage at each end and thickened to three pixels wide. Then extend the line to 35% and with this diameter draw a bounding box of sphere. This gives the VOI (volume of interest) by extending the VOI to one voxel background seeds are obtained. After grouping the foreground and background seeds the CA algorithm runs two times for the two groups and gives the probability maps. This is high level segmentation. Then RST reduct algorithm is used to classify the enhanced and necrotic cells. If user is not satisfied with the result then the algorithm can be repeated by increasing the number of iterations to get the better output.

Cellular automata iterative algorithm

Cellular automata is a discrete system of cells where in the next transition of cell depends on the current state of the cell and its neighbourhood. Each cell in the system can be correlated to each pixel in an image in digital image processing. A transition rule determines the next state of a cell taking the input as current state of a cell and its neighbours. Running a cellular automata algorithm is similar to the simulation of a image in discrete space. The most important feature of a CA is the updation of cells takes place simultaneously across the grid.CA has many applications in digital image processing such as reducing noise in image, outlining the edges, enhancing the image, dividing the image into different parts, recognizing the features etc.

Algorithm steps for Cellular Automata

1. Initialize cellular automata with user supplied tumour and background seeds.
2. 3x3 neighbourhood is considered in 2D.
3. Iterate automata for the initialized seeds with the transition function or pixel similarity function bounded to [0 1] which is obtained by the absolute intensity difference or gradient magnitude difference between the neighbouring nodes.
4. Update current state of automata by multiplying previous state with the maximum value of pixel similarity function.

Rough set theory

A non statistical tool used for the classification and analysis of data which is not precise or the data which cannot be characterized under an upper boundary or a lower boundary is called rough set theory. Any rough set contains a lower approximation (definitely belonging to the set), upper approximation (possibly belonging to the set) and a boundary region (difference between upper and lower approximation).The analysis and classification depends on the condition and decision attributes of an information table. For each condition attribute there will be a corresponding decision attribute that is performed when the condition is satisfied. But when the number of condition attributes is more the result obtained will not be accurate.

Reduct

There are some attributes in the information table which are more important than other attributes and are sufficient to represent the system. This subset of attributes is called reduct. In the table if we subtract relative data from headache and vomiting the resultant data is similar to original data with less number of attributes. In any system which is having huge data redundancy should be removed for better analysis. For this purpose reduct algorithm is used. Reduct gives the reduced number of condition attributes without changing the actual information. The attributes obtained from the reduct are subset of the original attributes without the loss of classification efficiency.

Steps for rough set algorithm using reduct

1. Image/Input from CA
2. Get Groups/labels from CA.
3. Find set of features for each pixel neighbourhood.
4. Use reduct to eliminate features.
5. Find group means for all features.
6. Check for each of the pixel minimum error.
7. ***If*** group ID change for local pixel features ***then***
8. Do changes
9. ***End***
10. Update image
11. ***If*** iterations done
12. Display based on target
13. ***Else***
14. Go to step 5.
15. ***End***

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III. FLOW CHART

Fig2. Overall Flow Diagram.

Input: Different imaging techniques are used to get the images of brain so that tumor can be diagnosed with its location and size of tumor like x-rays, CT scan and MRI. The input brain images are usually made in one of three orthogonal planes: coronal, horizontal (axial) and sagittal.

Preprocessing: Image enhancement involves a collection of techniques that are used to improve the visual appearance of an image, or to convert the image to a form which is better suited for human or machine interpretation.

Different stretching techniques have been developed to stretch the narrow range to the whole of the available dynamic range. Noise Filtering is used to filter the unnecessary information from an image. It is also used to remove various types of noises from the images. Histogram equalization is a nonlinear stretch that redistributes pixel values so that there is approximately the same number of pixels with each value within a range.

RECIST (Response Evaluation Criteria in Solid Tumors): is used to draw the longest diameter along the tumor. For the better identification and cover the tumor.

Volume of Interest (VOI): The tumor seeds and the background seeds are determined by using the line already drawn by the user to measure the longest diameter of the solid tumor. The seed selection procedure starts with a single line drawn by the user along the longest visible diameter of the tumor, focusing on tumor segmentation problem.

Cellular Automata (CA): A discrete system of cells where in the next state of cell depends on the current state of the cell and its neighborhood. Each cell in the system can be correlated to each pixel in an image in digital image processing.

A sequence of cells is a grid. Simplest is one dimensional. Grid can be implemented as N-Dimensional also. The number of states can be anything. Simplest is two states 0 and 1.As the no of states increases the complexity of CA increases. Neighborhood defines the number of cells surrounding a particular cell. In a one dimensional CA the simplest neighborhood is 3.

Transition Rule takes inputs current state of cell and the neighborhood and gives the next state of cells. CA has many applications in digital image processing such as image de-noising, edge detection, restoration, enhancement, segmentation, feature recognition etc.

Tumor Probability: the tumor detection is the challenging task in image processing by using one iteration it is impossible to distinguish the tumor and non tumor in brain. By using Cellular Automata it distinguishes the tumor and non tumor by comparing cell by its neighboring cell. Cellular Automata processed image is free of noise and unwanted things present in image are removed then by using the probability Strength maps are combined to detect the tumor.

Rough Set Theory: Rough set concept can be defined quite generally by means of topological operations, interior and closure, called approximations. A granule (set of adjacent pixels) is assigned to an object's lower approximation (and upper also) if all the pixels fall in its intensity range. If some pixels of the granule fall in the intensity range then granule will be considered in upper approximation (not part of lower approximation).

Necrotic: The tumor in brain is segmented by using rough set theory; the brain contains the soft cells, as the brain is affected by the tumor and soft cells become hard cells and these hard cells are separated from the soft tissue for the clear and better diagnosis of the patient.

IV. RESULTS AND DISCUSSION

If we look at the results and outcomes of the work many inputs are necessary. To begin with the very first image an input image is read and displayed:

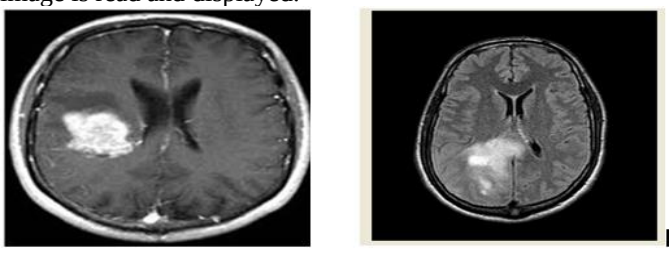

Figure 2. Sample Input Image For Segmentation

Figure.2 input is a typical tumor image. The processing steps and interim outputs of each one of them are to follow.

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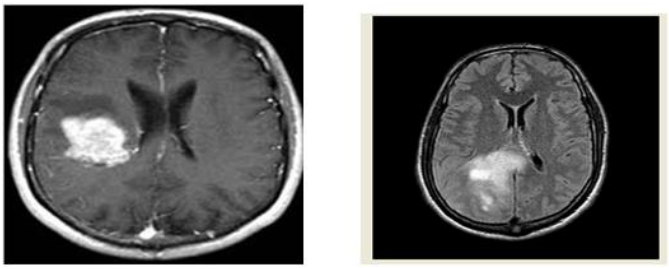

Figure 3. Gray scale version of input image

First the input image converted into grey scale image format. The image in Figure.3 shows the grayscale version of the input image.

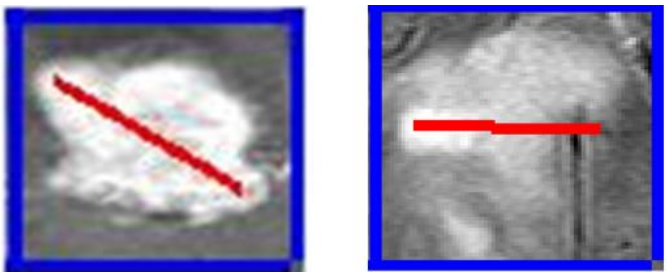

Figure 4. VOI of input image

Figure.4 depicts the voxel of interest that makes the foreground and background combined together to proceed further. As mentioned already the red line shows the foreground region where as the blue one bordered outline shows the background section.

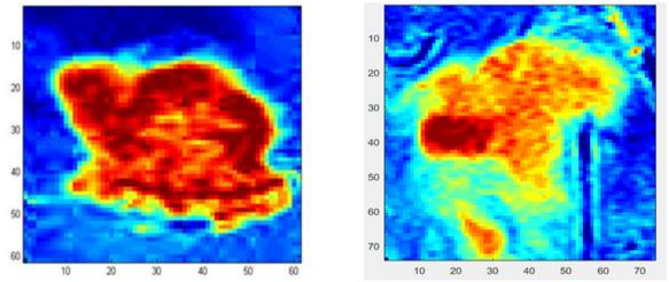

Figure 5. Foreground strength of ROI image

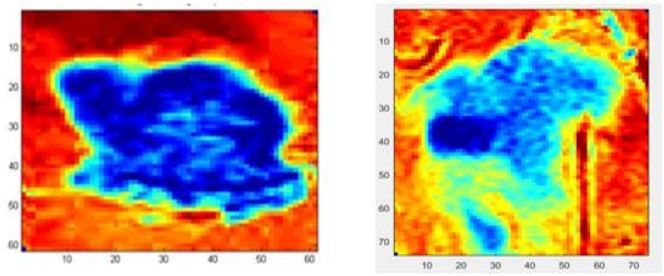

Figure 6. Background strength of ROI

The pixels that are said to be belonging to foreground or background vary in their strength as measure of belongingness to the assigned group. A pictorial presentation of strength map is given in Figure 5, for foreground strength. A high value or stronger affinity means dark red. It is not surprise that we can see some red patches out of the imagined region. In Figure 6, a similar depiction for back ground strength is shown. In both these cases blue makes case for strong opposite group affinity, where as a near yellow suggests the ambiguity. This ambiguity can be represented as a numerical metric by using the probability map. As shown in figure8

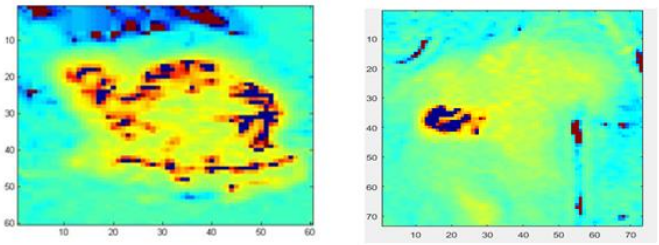

Figure 7. Probability map of the pixel group strengths

The dark patches observed belong to the third group which is indecision group. The surface image obtained from probability map is given as input to the rough set algorithm. As we know the features selected initially are:

feat = [Contrast, Correlation, Energy, Homogeneity, Mean, Standard Deviation, Entropy, Variance, Kurtosis, Skewness]and the values are:

attr = 16.3333 0.5000 0.3333 21.8889 26.0358 0.9911 541.1111 1.0829 0.2419 0.7083

the attributes are deleted after reduct and the values retained are:

attr = 21.8889

Hence only single feature here sufficient for segmentation is the homogeneity. Rough set algorithm takes multiple iterations around the selected attributes to arrive at segmentation. It is observed that single iteration takes time_rst = 27.6555 seconds, whereas for 100 iterations it takes 1065 seconds, which is about 18 minutes.

However for 29 iterations the RSA takes only 313.2635 seconds which is bit more than 5 minutes. The quality of segmentation for each of these is as shown in Fig. 9,10 and 11. From these three figures it is visible that for low number of iteration as 9, the segmentation is rough one while 29 iterations offer a crisp bound segmentation. Looking at figure 10 and 11, it is inferred that the segmentation attained after 29 iterations are as good and close as they are after 100 iterations.

Figure 8. RSA, 9 iterations segmented image

Figure 9.4 RSA, 29 iterations segmented image

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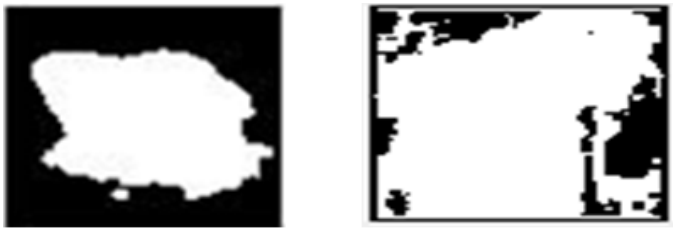

Figure 5. RSA, 100 iterations segmented image

V. CONCLUSIONS

The world is moving more towards technology dependent era. The expertise in medical fields is as good as finding needle in haystack. Since the opinion of an expert can vary from that of novice. Lack of the expert medical practitioner in the locality should not be an obstacle for the patient of rural habitat. Hence for the benefit of all it is advisory to make the most use of the technology available to infer or conclude for treatments. The CA-RST combined segmentation methods bring this aspect to reality, by analyzing the inputs and helping the doctor in pin pointing the areas of disease region, where lot of precision is required. The accuracy of results is dependent on iterations and the varying pixels combinations of the group that exhibit dynamic statistical property. However the results obtained from given images are very encouraging.

VI. FUTURE WORKS AND IMPROVEMENTS

CA is a natural process defining algorithm. By observing the malignant cell multiplying time as an epoch we can predict the status of the foreground and background cells in advance for the set surgery day. This can solve an unnecessary panic if there was a long delay between MRI scan and surgery. While implementing RST feature set are chosen to be mere number set that varies from pixel of one group to another, it is well known aspect that the statistical features can be used for more than mere numerical aspects. It is to be observed in case of brain images whether the reduct properties of brain tumour and Alzheimer are different from each other, hence this work can be extended to other disease identification as well. With the proper database this method can be applied to more diseases. Example: liver diseases, skin cancer, breast cancer identification and classification etc.

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