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Single Tumor Growth Analysis: Cellular Automata Segmentation

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Abstract: *Brain tumor is one of the most life-threatening diseases and hence its detection should be fast and accurate. Medical imaging techniques are used to detect tumor which includes magnetic resonance imaging, computed tomography, positron emission tomography etc. MRI is commonly used in the medical field for detection and visualization of details in the internal structure of the body. In this work MRI images are used to find the analysis of tumor growth. Region of interest is segmented from the MRI image in order to find the tumor growth. Many automated techniques which use image segmentation have been proposed. They show less accuracy as well as 3more time consumption. This thesis focuses on simulating tumor growth with cellular automaton (CA), it is able to segment brain tumor volumes quickly and accurately than the existing segmentation techniques. Segmentation is followed by tumor growth prediction. In this work, a method that uses streamlines to divide a 3-D region of interest into units where local properties can be measured over the paths of growth is proposed. The method can be evaluated on simulated tumors, and medical images of brain tumors. This method is suitable for mapping amorphous dynamic objects. 90% accuracy and lower time consumption is observed.*

Keywords: *Brain Tumor, MRI, Cellular Automata, Registration.*

1. INTRODUCTION

The body is made up of many cells which have their own special function. Most of the cells in the body grow and divide to form a new cell of the same kind as they are needed for the proper functioning of the human body. When these cells lose control and grow in an uncontrollable way. It gives rise to a mass of unwanted tissue forming a tumor. Brain tumor is a mass of tissue which cells grow and multiply uncontrollably. Early detection of brain tumor is necessary as death rate is higher among humans having brain tumor. Tumors are generally classified based on the location of their origin and its malignancy. There are two types of tumors based on the location of the origin of tumors. Primary brain tumor and metastatic brain tumor. Primary tumors originate in the brain cells and sometimes they spread to other parts of the brain or to the spine. But spreading to other organs occurs only rarely. But the metastatic brain tumors or secondary brain tumors are those which originate in other parts of the body and then spread to the brain. These tumors are named according to the location which they originate. Based on the malignancy of tumors originated, they are classified as benign and malignant brain tumors. Benign tumors are the least aggressive ones. They originate from cells within the brain or from associated parts of the brain and they will not contain cancer cells. They only grow slowly and also they have clear borders i.e. their growth are self-limited and they will not spread into other tissues. While malignant brain tumors contain cancerous cells and their growth is not self-limited. Also their borders are not clear and they grow rapidly and invade surrounding brain tissues. Hence they will become life threatening if proper treatment is not taken at the correct time. Medical imaging technique is used to detect tumor. Different types of imaging techniques like magnetic resonance imaging (MRI), computed tomography (CT), positron emission tomography (PET) etc. exist for the diagnosis of brain tumor. MRI is commonly used in the medical field for detection and visualization of details in the internal structure of the body and is basically used to detect the differences in the body tissues which have a considerably better technique as compared to computed tomography. CT uses ionizing radiation while MRI uses strong magnetic field and it provides greater contrast between different soft tissues of the human body. Experts can detect brain tumors manually from the MRI images but manual segmentation faces some difficulties such as over-time consumption, chances of variation of results from expert to expert.

Brain tumor segmentation is very difficult due to complex brain structure but early and accurate detection of tumors, edema and necrotic tissues is very important for diagnostic system. Tumors can damage normal brain cells by producing inflammation, exerting pressure on parts of brain and increasing pressure within the skull. Automatic brain tumor detection and segmentation face many challenges. Brain tumor segmentation requires the efficient knowledge of pathology and understanding the intensity and shape of MRI image. The main problem in tumor segmentation arises due each tumor being of different shape and shape. Different methods are there for semi-automatic detection of brain tumors but they also require human intervention which again makes the process

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time-consuming and expensive. There comes the importance of automatic brain tumor detection techniques from the medical images. They should be self-explanatory and easy to operate for the radiologists. The image segmentation is the process of partitioning a digital image into multiple segments. In this work a contour based segmentation is used for the detection of brain tumor from the dataset containing MRI images of a patient. Prior to segmentation, image registration is done on the two MRI images of the same patient taken at different periods of time. Registration [1] is the process of overlaying two or more images of the same scene taken at different times from different viewpoint. It geometrically aligns two images i.e., the reference and the sensed image. As tumor shape usually changes in time, comparison of images of the tumor acquired at different time points (e.g., before and after the course of radiotherapy) is limited in showing in which region tumor growth or shrinkage has occurred. To make the result more accurate after the registration segmentation is further performed on the registered MRI image.

In this work cellular automata segmentation is performed ignorer to segment brain tumors. After segmentation tumor growth is also predicted. A method that uses streamlines to divide a 3-D region of interest (e.g., tumor) into units where local properties can be measured over the paths of growth is proposed. The parameters such as directional length and mean intensity can be measured locally at sequential time points and then compared. The method is evaluated on simulated tumors, and medical images of brain tumors. The evaluations suggest that the method is suitable for mapping amorphous dynamic objects. The method is based on projecting (2-D or 3-D) a region of interest (ROI) from an internal reference (core) point to the exterior surface, using streamlines as an indicator for tumor local direction of growth. This allows the placement of tumors into a standard coordinate system despite their amorphous shape. Further, with the modest requirements of rigid alignment and moderate movement, spatial correspondences over time are obtained allowing local outcomes to be referred to. The correspondence of the streamlines to the local tumor growth was tested on simulated tumor images.

2. RELATED WORK

As tumor shape usually changes in time, the comparison of the images of the tumor acquired at different time points (e.g., before and after the course of radiotherapy) is limited in showing in which regions of the tumor growth or shrinkage has occurred. Spatial mappings can be obtained using registration, either rigid [2], or nonrigid [3]. Several authors suggested various algorithms for registration. B. B. Avants, C. L. Epstein, and J. C. Gee [4] develop a novel symmetric image normalization method (SyN) for maximizing the cross-correlation within the space of diffeomorphic maps and provide the Euler–Lagrange equations necessary for this optimization. They used Thirion's Demons algorithm. It produces better performance but was not robust. J. Corso, E. Sharon, S. Dube [5] present a new method for automatic segmentation of heterogeneous image data thattakes a step toward bridging the gap between bottom-up affinity-based segmentation methods and top-down generative model based approaches. They use weighted aggregation algorithm. Even though it was highly robust this algoritham was not effective since the detection and quantification of brain tumor is very difficult. E. Konukoglu, O. Clatz, B. Menze [6] propose a parameter estimation method for reaction-diffusion tumor growth models using time series of medical images. Parameter estimation method segmentation algorithm is used.it has an advantage of high accuracy but lack diffusion tensor imaging for the patients. S. Jones, B. Buchbinder, and I. Aharon [7] present a novel computerized method of examining cerebral cortical thickness. Algorithm used is warping algorithm and adaptive algorithm. it has less sensitive to local segmentation errors but has High computing power. Its disadvantage is due to the limitation of signal contrast and image resolution. After the registration the registered image is segmented using different algorithms. Jianping Fan,Yau Elmagarmid & Aref's [8] paper presents an automatic image segmentation method using thresholding technique. This is based on the assumption that adjacent pixels whose value (grey level, color value,texture, etc) lies within a certain range belong to the same class and thus, good segmentation of images that include only two opposite components can be obtained. Jaskirat Kaur, Sunil Agrawal & Renu Vig.'s paper presented thresholding and edge detection being one of the important aspects of image segmentation comes prior to feature extraction and image recognition system for analyzing images. It helps in extracting the basic shape of an image, overlooking the minute unnecessary details. In this paper using image segmentation (thresholding and edge detection) techniques different geo satellite images, medical images and architectural images are analyzed [9]. Dzung L. Pham, Chenyang Xu, Jerry L. Prince proposed the basics that thresholding approaches segment scalar images by creating a binary partitioning of the image intensities. It attempts to determine an intensity value, called the threshold, which separates the desired classes. Segmentation is achieved by grouping all pixels with intensity greater than the threshold into one class, & all other pixels into another class. Determination of more than one threshold value is a process called multi thresholding.Rajeshwar Dass, Priyanka, Swapna Devi's paper describes the different segmentation techniques used in the field of ultrasound and SAR Image Processing. Firstly this paper investigates and compiles some of the technologies used for image segmentation. Then a bibliographical survey of current segmentation techniques is given in this paper and finally general tendencies in image segmentation are presented [10]. Selva kumar's paper deals with the implementation of Simple Cluster Algorithm [11] for detection of range and shape of tumor in brain MR images. This uses computer aided method for segmentation (detection) of brain tumor based on the combination of two algorithms. At the end of the process the

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tumor is extracted from the MR image and its exact position and the shape also determined & the tumor's stage is displayed based on the amount of area calculated from the cluster.S. Thilagamani and N. Shanthi's paper is a survey on different clustering techniques to achieve image segmentation. In order to increase the efficiency of the searching process, only a part of the database need to be searched. For this searching process clustering techniques can be recommended. Clustering can be termed here as a grouping of similar images in the database. Clustering is done based on different attributes of an image such as size, color, texture etc. The purpose of clustering is to get meaningful result, effective storage and fast retrieval in various areas [12].

3. PROPOSED WORK

In this work MRI images are taken. The images are collected from the website http://www.sadies-brain-tumor.org/mris/. The dataset contains two set of images taken at two different months. Each set contains MRI images of the patient at different angles. Since tumors are amorphous in shape their growth can't be predicted accurately. There for different slices of MRI images are taken as shown in the figure 1.

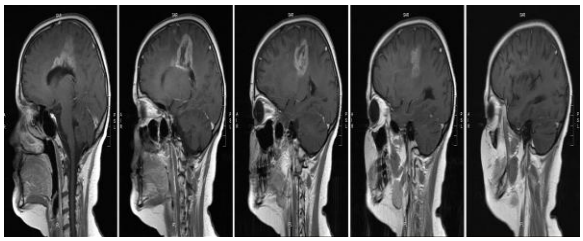

Figure 1: MRI Images of same patient taken at different angles at first month

Patient undergoes radiation as a part of treatment. After the radiotherapy tumor area might reduce its size. After radiotherapy MRI is taken as shown in figure 2. Sometimes MRI shows the tumor area as such. But it may not be the tumor instead it might be the scar tissues left after the radiation which has got the same intensity of the tumor. There for an efficient method to identify tumor is being proposed. In order to compare the growth of the tumor after the treatment another set of MRI is taken.

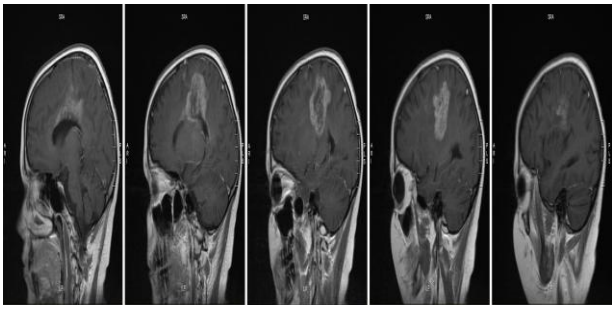

Figure 2: MRI Images of same patient taken at different angles in second month

Preprocessing is the next step; it is done to resize the image. That is to convert the input image into a standard size image (e.g.: 256 x 256). Here we are taking grayscale mri images. Preprocessing of brain MR image is the first step in our proposed technique. Preprocessing of an image is done to reduce the noise and to enhance the brain MR image for further processing. The purpose of these steps is basically to improve the image and the image quality. Then apply registration on the two MRI images taken at two different time periods shown in the figure 3. Registration is the process of overlaying two or more images of the same scene taken at different times from different viewpoints. It geometrically aligns two images, the reference image and the sensed image as shown in figure 3. There are two types of registration rigid and non rigid. Rigid or affine registration is performed here. The affine transformation preserves the straightness of lines, and hence, the planarity of surfaces and it preserves parallelism, but it allows angles between lines to change. It includes Translation, Rotation, Scaling and Shearing. Keeping one image as fixed overlap the other image and adjust it by applying the transformations in order to get the registered image. It is shown in the figure 4.

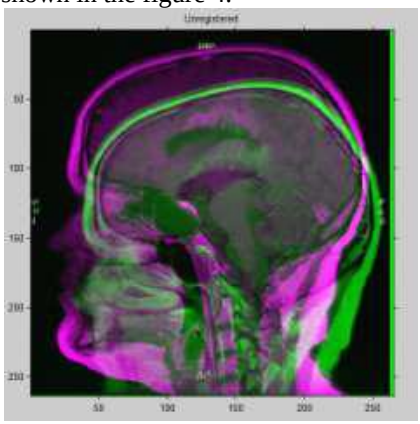

Figure 3: Unregistered MRI Image

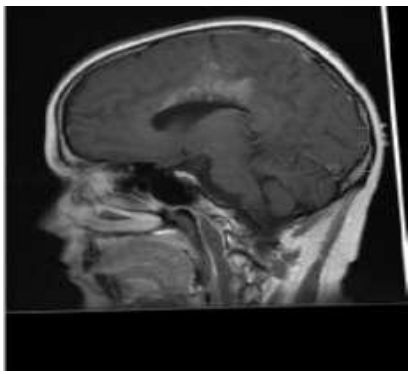

Figure 4: Registered MRI image Image

After registration segmentation is performed. Segmentation is done to separate the image foreground from its background. Segmenting an image also saves the processing time for further operations which has to be applied to the image.

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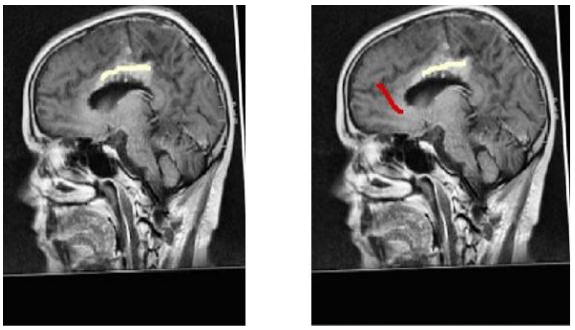

Figure 5: Foreground region marked as white line and Background region as red line

Cellular automata [14] based segmentation is used. Steps of the proposed cellular automata based tumor segmentation [13] algorithm includes: First the user draws a line over the largest visible diameter of the tumor; using this line, a VOI is selected with foreground (white)-background (red) seeds as in figure 5; then tumor CA algorithm is run on the VOI for each two sets of seeds (for the foreground and background) to obtain strength maps for foreground and background at each voxel two strength maps are combined to obtain the tumor probability map and a level set surface is initialized and the map is used to evolve the surface which converges to the final segmentation map. Finally, the regions of the tumor is segmented using a CA based method with the chosen enhanced and seeds. This is shown in the figure 6.

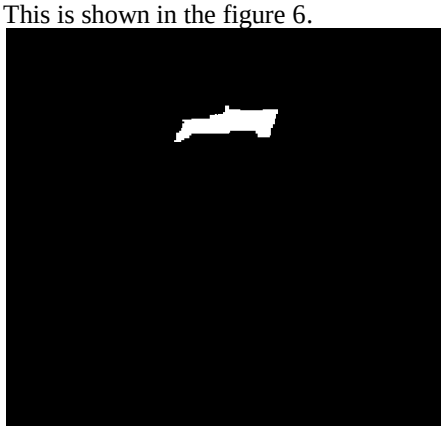

Figure 6: Segmented Tumor

Thus tumor is segmented accurately using a cellular automata segmentation followed by feature extraction of the tumor region and projecting into a 2D graph using streamlines and finally tumor growth is calculated.

Feature extraction is used to measure the features of the tumor. The two features are optical flow features and laplacian streamline features. After obtaining optical flow features streamlines are computed.

Streamlines are obtained by a function that contains list of points i.e., image positions (x,y) position. Streamlines are drawn by displaying these points graphically i.e., draw line by connecting those coordinates. Streamlines are estimated in each point. With the horizontal and vertical direction obtain the motion vector. 3 slices of mri images are taken. First after finding the motion vector, find the difference of image 1 and 2. Then find the difference of image 2 and 3. Thus angle is estimated and by converting coordinates to polar projection is done.

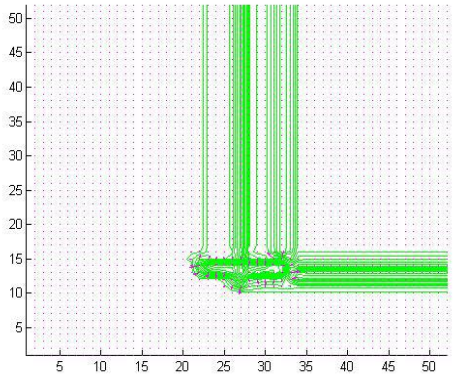

Figure 7: Streamlines

Projection [15] process is based on the constructed streamlines and is performed by projecting the outer surface onto a sphere. Projecting the ROI Surface onto a Sphere Once the desired properties have been measured inside the ROI, based on the internal stream-lines, the calculated values are stored in correspondence to the boundary voxels which are the starting points of the streamlines. The ROI surface topology is then simplified by projecting it onto a sphere. Assign each coordinates into a virtual 3D sphere from a 2D image. Motion vector features obtained contains the horizontal and vertical values, they are converted from cartition to polar coordinates in order to project into a 3D sphere. i.e.; from (x,y) coordinate to coordinate. From the variation growth is obtained. Since 360degree variation in 3D is sphere and 360degree variation in 2D is circle consider all degrees to estimate the angle.

Compare the different slices of image whose angle is estimated in the above step. At which angle growth is formed can be obtained through the amplitude value of the azimuth variation. Azimuth variation of MRI images of first two slices is shown in the figure 8. Azimuth variation of second and third slice is also calculated and their mean is taken.

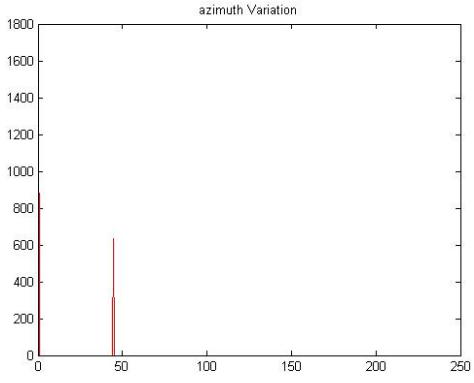

Figure 8: Azimuth Variation

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Motion vector variation shows the movement of tumor from the first image to the second image. Motion vector variation of first two slices of MRI images is shown below. Motion vector variation of second and third image is also calculated and their mean difference is taken. Amplitude value of motion vector variation shows at each angle how much growth occurs. Mean difference shows the average tumor growth of that patient. Motion vector variation of first two slices is shown in the figure 9. This work is simulated in MATLAB.

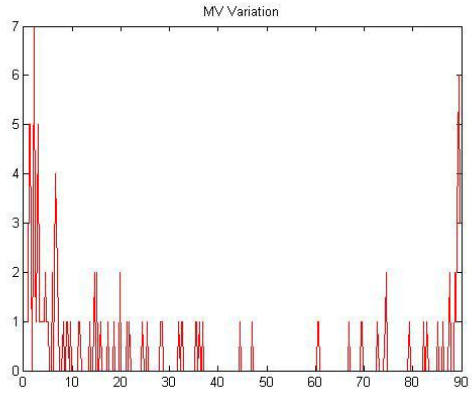

Figure 9: Motion Vector Variation

4. RESULT AND DISCUSSION

Here 3 slices of MRI images taken at different months are taken to detect tumor and predict the tumor growth. Registration is done on the two images of two different time periods. Registration is followed by segmentation. Azimuth variation and motion vector variation of the 3 registered images are calculated from the computed streamlines. In the proposed system cellular automata based segmentation is used for identifying the tumor growth but in the existing system many segmentation methods are available one such is contour based segmentation. To calculate the performance of the proposed and existing system a receiver operating characteristic curve is plotted. The true positive rate and false positive rate are calculated and plotted for getting an ROC curve. Figure 10 shows the Receiver operating curve.

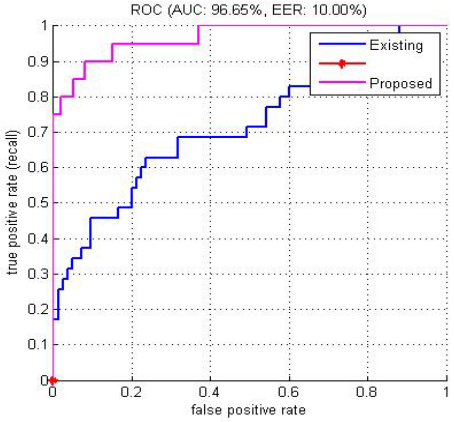

Figure 10: ROC curve

From the figure it is clear that the proposed method is better than the existing method. The diagonal cuts the magenta line at TPR value 0.90 there for accuracy is 90 % and expected error rate(EER) is only 10 % and it cuts the blue line at TPR value 0.65. There for the proposed method is better. Time consumption graph shows proposed method takes less time than existing method. There for proposed method is better than existing method. Time consumption graph is shown in the figure 11.

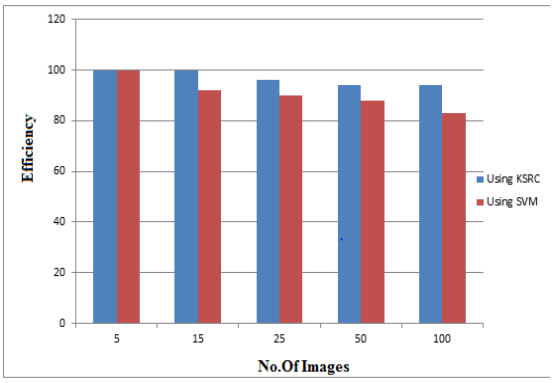

Figure 11: Time Consumption of proposed v/s existing method

5. CONCLUSION AND FUTURE WORK

Brain tumor is one of the most life threatening diseases and hence its detection should be fast as well as accurate. In order to reduce the death rate of patients, tumor should be detected at an earlier stage. Magnetic resonance images are used as a tool to detect the tumor growth in brain. Manual segmentation cant segment the tumor region accurately as tumor is amorphous. In this work cellular automata segmentation is used to segment the tumor region and growth of the tumor is being predicted. Tumors are represented as ROIs in the image where a reference (core) point is defined. Finally, a set of streamlines is constructed from the ROI surface (boundary) to the core point and it is projected to a sphere. Motion vector variation and azimuth variation are calculated to detect the direction and angle of growth of the tumor. Accuracy of 90 percent is obtained which is better than the existing method. Also time taken by the proposed method is lesser than existing method. The future scope of the proposed work is that it can be extended to detect multiple tumors from a single MRI image.

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