Analysis of Cancer Growth using Modified EDEN Model

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Abstract-The change of biomedical quantities and the appearance of pathological patterns are the early signs of disease, and only an earlier detection can increase the chances of significant reduction of mortality and morbidity of patients. The simulation techniques are very helpful in the field of biomedical imaging for by simulating the desired model. Medical Image processing provides a convenient way of a rapid and early detection of pathological changes in an objective manner which otherwise might be missed by the human investigator. The field of medical simulation is growing rapidly during the last years. Our aim is to characterize the brain cancer with the help of simulation using modified Eden growth model.

I. INTRODUCTION

Brain tumor: A brain tumor is uncontrolled cellular growth with-in the brain or inside the skull. These tumors can be divided as benign or malignant.
. They can be *benign* (no cancerous, meaning that they do not spread elsewhere or invade surrounding tissue) or *malignant* (cancerous).Malignant brain tumors are further classified as either *primary* or *secondary* tumors. Primary tumors start in the brain, whereas secondary tumors spread to the brain from another site such as the breast or lung. Main regions of brain are [2]:

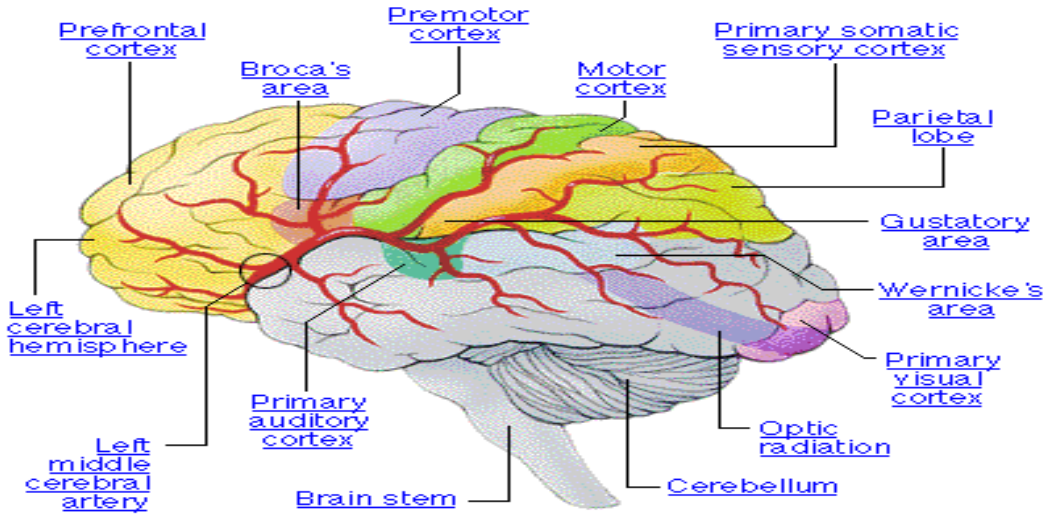


Figure 1: Major regions of brain [16]

1.1 Benign Tumors:

Benign Tumor

Benign tumors[13] grow slowly, have defined edges and do not invade other body parts. Benign tumors can be life threatening as they exert pressure on normal brain tissue and skull which causes inflammation and brain swelling and thus interfere with normal functioning of brain. Majority of brain benign tissue arise from brain and brain associated tissues.

1.2 Primary Malignant Brain Tumors

Primary brain tumors begin in brain itself and can be either malignant or benign. They are named after the types of cells they contain or depending upon the part of brain where they begin. For example tumors originating in glial cells are called gliomas. CNS tumors rarely spread outside the system.

1.3 Secondary (Metastatic) Malignant Brain Tumors

Secondary brain tumors are caused by cancerous cells which begin in non-CNS part of the body and then invade CNS. These tumors are named after the type of cancer which invades brain tissue. If people have more than one secondary tumor in the brain, sometimes it is called as multiple brain secondarie.

- The normal brain cells from which they originate.
- The location in which the cancer develops.

The biologic diversity of these tumors, however, makes classification difficult, and some experts believe that more specific categories are needed.

1.4 Category

Our aim is to characterize brain tumors by using cellular automata based simulation models.

Before beginning a discussion on tumor growth, some background on the meaning of eden growth and "fractal" is described further. The word fractal was first accidently discovered and coined by Benoit B. Mandelbrot who is known as father of fractals in 1970's. He used the Latin term "fractus" which means broken to name fractals. Because of irregular shape cancerous growth can be described with the help of fractal parameter.Recent studies have shown that tumors have fractal dimension and so fractals can be used to describe their pathological architecture. Fractals can be defined as rough geometric shapes which can be divided into small parts, each of which is a reduced size copy of the whole [4, 11, 12] . With cellular automata it is possible to analyze the spatio-temporal dynamics at cellular level [3]. Cellular automata are discrete dynamic systems which were introduced by john von Neumann and stanislaw ulam as a computer model for self reproduction (von Neumann 1966).

Mass fractal dimension: Mass fractal dimension is used for calculating fractal dimension [6, 14]. It is valid for irregularly shaped objects. Mass, M may be equated with the algebraic sum of the gray values contained in the image object.

Mass fractal dimension is also used to calculate the fractals of irregularly shaped objects. For calculating mass fractal dimension of N points of D dimension each, the total mass is divided into cells of fixed size. The size of cell size is r. then by plotting the points of cells versus r in the scale of log is mass fractal plot. The slope derived of this plot gives us the mass fractal dimension

Perimeter Fractal Dimension: Perimeter fractal dimension [1] is also one of the techniques to calculate the fractal dimension. In this process the ratio of perimeter to the area is found for the fractal. Logarithm of area on the vertical axis versus the logarithm of perimeter on the horizontal axis is plotted. If the relationship is indeed fractal, this plot will follow a straight line with a positive slope. The estimation of perimeters and areas has to be done over a range of d (here it is between 1 – 2).

Minimum Circle Dimension: Minimum circle dimension is defined as the fraction of the outlined circular area from which we can extract the dimensionality for pattern recognition. It should lie between 0-1 for problem under consideration. Minimum circle dimension is a parameter feature for measuring the smoothness of an image [5].

In order to find minimum circle dimension we have to first find centre of gravity of the segmented image. Then find the distances from the centre of gravity to the edge of the segmented tumor image. Taking the maximum distance as radius we draw a hypothetical circle and find the ratio of the segmented image to this hypothetical circle. This ratio should lie between 0 to 1 and is the minimum circle dimension. In order to find minimum circle dimension we have to first find centre of gravity of the segmented image. Then find the distances from the centre of gravity to the edge of the segmented tumor image. Taking the maximum distance as radius we draw a hypothetical circle and find the ratio of the segmented image to this hypothetical circle. This ratio should lie between 0 to 1 and is the minimum circle dimension [7-8].

II. PROPOSED ALGORITHM

As tumors grow at different rate and follow different pattern of growth so because of this biological diversity it becomes difficult to characterize them. However tumor diagnosis requires perfect pattern recognition. So the purpose of this study is to explore the use of fractal analysis [15] to characterize and classify different types of tumors. If a tumor is benign then it can be removed surgically however a malignant tumor spreads through-out the body. So the second objective of this study is to predict the growth of a tumor[17] that is whether it is benign or metastatic and if it is benign then whether it will grow into a metastatic tumor or not. Eden growth model is well known technique for simulating tumor growth [3]. We have developed the modified Eden models for tumor growth. The algorithm developed for modified new_eden11 model is given below.

Algorithm for new and modified new_eden11 model

1- Input the three parameters such as eden_list,neighbor_list,cell_size,iter_no into our new_eden11 function.
2- Repeat step 3 to step 14 upto the iter_no-1 times.
3- Calculate size of neighbor_list using [row1,col1] = size(neighbor_list) and generate random numbers using formula r = rand(1,row1); r = r/sum(r).
4- Find the mean of eden_list and generate newdistances using fomula nd = ones(1,row1)*(1/row1);
5- Calculate indices of r<=nd and add those indices to neighbor_list and assign those as new points.
6- Add new_points to eden_list and find the size of increased eden_list.
7- For iteration one to length of new_points, update neighbor_list with new_points using update_list.
8- Assign new_neighbors =[];
9- For iteration one to length of new_points, find newneighbors using formula new_neighbors1 = [xn(p) + cell_size, yn(p); xn(p), yn(p) + cell_size; xn(p) - cell_size, yn(p); xn(p), yn(p) - cell_size];
10- Now add newneighbors calculated with formula to the initial new_neighbors.
11- Again calculate the size of neighbor_list using formula [row1,col1] = size(neighbor_list).
12- Now for j = 1:row1, update newneighbors using formula new_neighbors = update_list(new_neighbors,neighbor_list(j,:));
13- Now for k = 1:row2 update newneighbors using formula new_neighbors = update_list(new_neighbors,eden_list(k,:));
14- Plot the eden growth model using eden_list.
15- Show the binary image.

In the same way we have used new_eden22 and new_eden33. The difference lies amongst all the Eden model is of probability distribution.

III. RESULT AND DISCUSSION

In this section of work, we will show the results of simple Eden model and modified Eden model and try to clarify the differences between them. Results produced from simple Eden model is compact in visualization whereas the images produced by modified Eden model are rough images i.e. they are not compact. Fractals generated from the images produced by both the model are shown below in table1. All the values of simple Eden model are greater than the modified Eden model. Images grown by modified Eden model are growing fast. It can be used to simulate the cancerous images.

As the speed of growing cancerous images are also very fast. Therefore we can say that our new and modified Eden model is capable of diagnosing the cancerous images. All the above mentioned things are clearly shown in following figure3 and table1. In the following figure4, three images are produced by both model by using three different probability based random numbers.

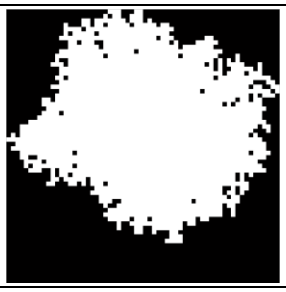
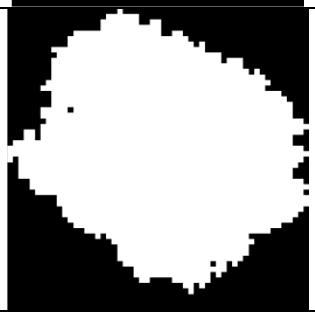
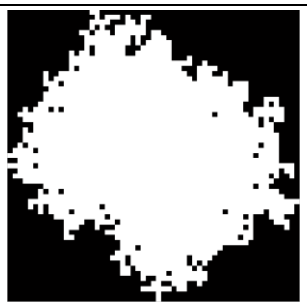
Images grown by simple Eden model	Random number drawn from	Images grown by parallel Eden model
	Uniform Probability Distribution	
	Normal Probability Distribution	
	Exponential Probability Distribution	

Figure3: Generated images from both simple and modified Eden model

Fractal dimension for Images grown by simple Eden model	Random number drawn from	Fractal dimension for Images grown by parallel Eden model
1.9036	Uniform Probability Distribution	1.9007
1.8898	Normal Probability Distribution	1.8031
1.8889	Exponential Probability Distribution	1.8736

Table1: Fractal dimension calculated from both simple and modified Eden model

Above result is generated by applying our modified Eden model on simulated data generated by simple Eden model. Above results will play an important role in validation work. Now we will show the following result generated by applying proposed modified Eden model on experimental data[7,8].

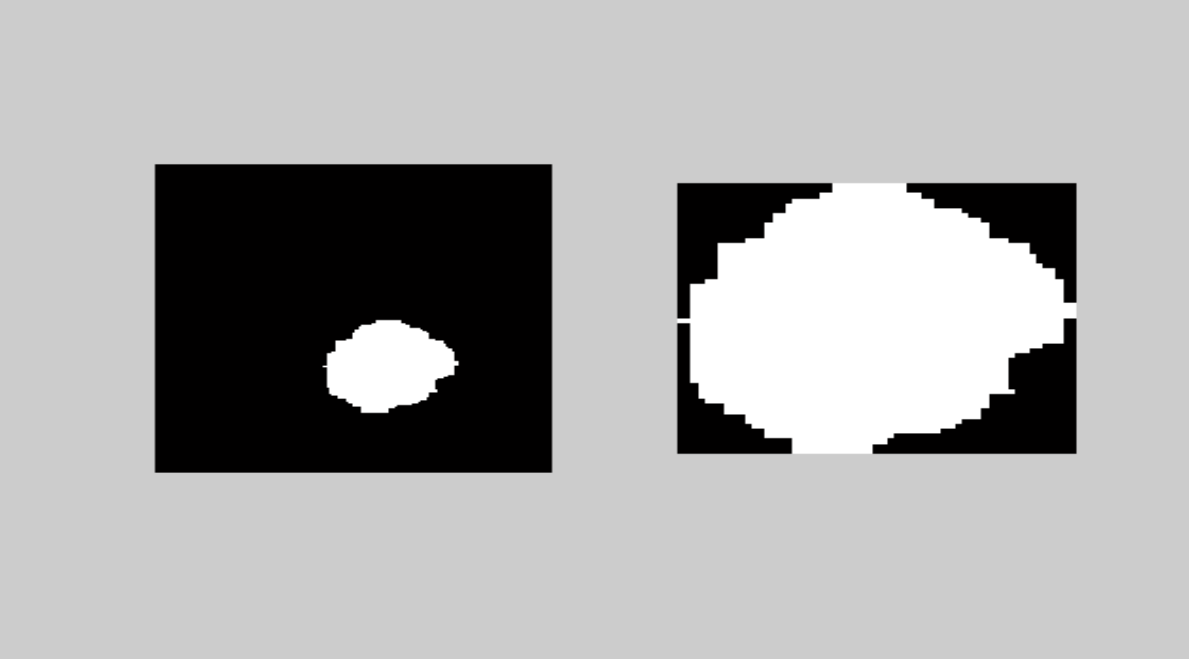


Figure4: Grown experimental images using modified Eden model

Fractals[18] play an important role in descriptions of irregular shapes. Roughness of an object can be well measured by applying fractal calculation technique. Fractals of experimental image is shown below.

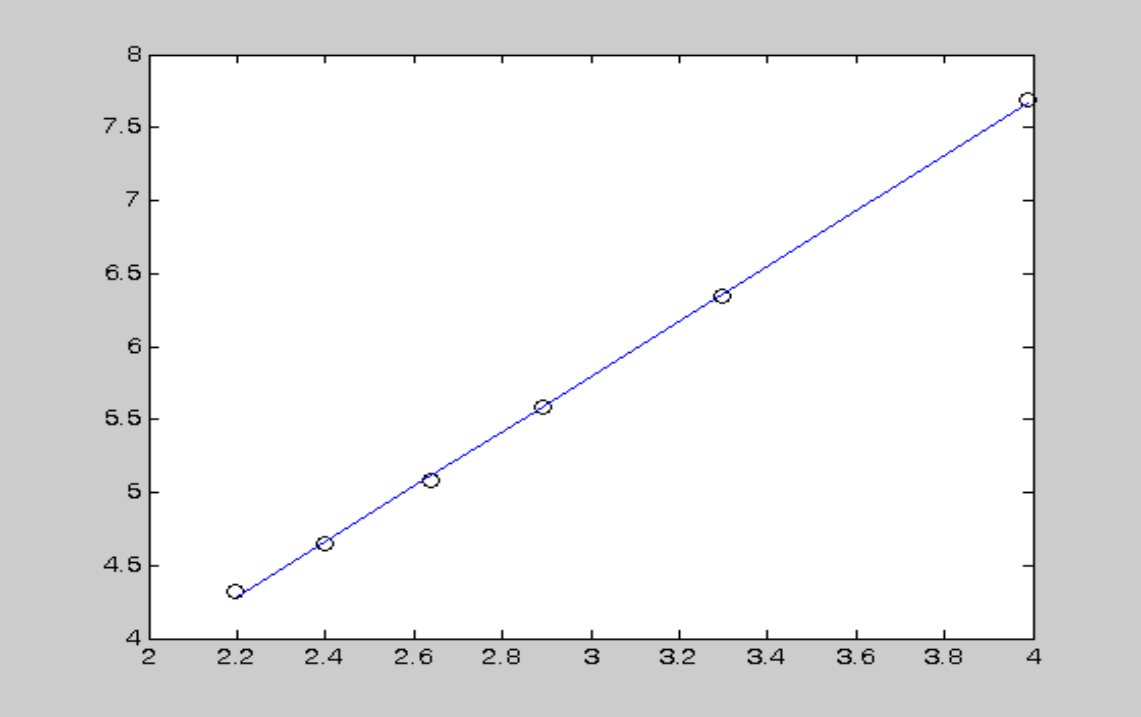


Figure5: Fractal graph of experimental data

Fractal dimension computed from simulated objects

dz1	dz2	dz3	dzz1	dzz2	dzz3
1.9064±0.0189	1.8996±0.0238	1.8967±0.0200	1.8626±0.0257	1.8532±0.0277	1.8541±0.0203

Fractal dimension computed from experimental cancer images is:
ex_c = [1.7539 1.8742 1.8759 1.7156 1.8922]; Mean = 1.8224±0.0814;
ex_t = [1.9127 1.9440 1.9272]; Mean = 1.9280±0.0157

From the above results of fractal dimension computed from simulated objects and computed from experimental cancer images, we can say that growth pattern of cancerous image is matching with growth pattern of simulated images by using Gaussian probability based random numbers. In modified Eden model , neighbors grow in parallel. We can say that it is following geometric progression (GP). Ni+1= ni*2. Geometric progression means our clusters are growing parallel with the application of modified Eden model. Growth of caner is also very fast i.e. it grows in parallel order. We can say that our modified Eden can be used for cancer growth.

IV. CONCLUSION

A new method to characterize brain tumor with help of simulation and analysis of actual tumor image growth properties has been proposed. The specific parameters of the images are matched and interpreted from both of the images. and hence modified method produces the better results. This work provides you a better visualization of tumor growth which was not possible earlier and gives better information regarding its future growth which can be useful for surgeon who is involving in diagnosis of tumor. Because we know that tumor is a junction of different cell in brain i.e. Nerve cell and Muscle cell. So its characterization hopefully helps the concerned surgeon or physician to plan better therapeutics. We worked on 10 different simulation images and then calculated its corresponding feature values shows that we need better classification method and finer class also. This work needs to be fined tuned as we have already discussed that simulated tumor's feature value correspond to cluster. We need more fine division of Eden and New Eden model iterations which could give strong evidence. We worked on three different growth model techniques which could be increased to more probability based random numbers to produce more efficient results. Further improvements in classification accuracy can be expected with more careful experimentation.

REFERENCES

[1] Barnsley, Michael F., "Fractals Everywhere", 2nd Edition. AP Professional, 1993.
[2] Florian E. W. Schmidt, "Development of a Time-Resolved Optical Tomography System for Neonatal Brain Imaging, Basic Anatomy and Physiology of Human Brain", 1999, pp: 27-29.
[3] Sabine Dormann and Andreas Deutsch, "Modeling of self-organized avascular tumor growth with a hybrid cellular automaton", In Silico Biology 2, 0035 (2002);©2002, Bioinformation Systems e.V
[4] Mitchell j. Figenbaum. "Chaos and fractal new frontiers of science", 1992
[5] Larry S. Liebovitch. Fractal in Biology.
[6] Aggregate Growth: Mass fractal and DLA concept
[7] http://cyberknifeservice.com/ck_brain_spine_cancer.html
[8] http://vision.cse.psu.edu/research/tumorDetect/index.shtml
[9] Paul A. Fishwick, "What is Simulation", University of Florida, USA, EDT 1995.
Available: http://www.cise.ufl.edu/~fishwick/introsim/paper.html .
[10] Gene Bellinger, "Modeling & Simulation: An Introduction", 2004. Available:
http://www.systems-thinking.org/modsim/modsim.htm
[11] Wolfgang Bauer. Cancer Detection via Determination of Fractal Cell Dimension,
[12] James W. Baish and Rakesh K. Jain, 2000 Fractals and Cancer,
[13] http://www.umm.edu/index.htmUniversity of Maryland, Medical Centre of University.
[14] Yacov Kantort and Yonathan ShapirS, 1985.Crossover behaviour of truncated Eden models
[15] Tapobrata Lahiri and Dwijesh Dutta Majumder, Fuzzy multi fractal approach in the study of texture complexity in an image database.
[16] Atlas of the Body, The Brain effects of the strokes", Medical Library, Medem
Available: http://www.medem.com/medlib/print/ZZZ0ZFP46JC.
[17] Jason Twamley, "Cluster Growth Models", 2003.
Available: http://www.thphys.may.ie/CompPhysics/homework/third/descriptions/clusters/clusters/clusters.html
[18] Branka Spehara, Colin W.G. Cliffordb, Ben R. Newellc, Richard P. Taylor," Universal Aesthetic of fractals", Computers & Graphics 27, 813–820, 2003.