Simulating Various Types of Tumor Growth using Eden Model and its Modified Form

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Abstract - Recent studies have shown that extracting rule for tumor growth or cancer growth is big medical challenge. Growth structure of tumor can be described by Simulation process. It generates the insight structure of tumor growth. Eden model is able to describe the irregular shapes like cancer growth or tumors.. This paper outlines the basic simulation methods of tumor growth by using different probability based random numbers. By applying these different growth model, on cellular automata, different growth pattern are generated. Here we have formulated new approach to characterize brain tumor using fractal dimensions.

I. INTRODUCTION

Eden model is a process which describes the growth very simply.Eden model uses simple protocol to increase the member of cluster. grid responds to its neighboring cell by growing, dying, migrating etc. [James W et al 2000].. To grow Eden model a seed particle is placed at a single infected site or origin (x =0, y = 0). Cluster grows iteratively by adding more particles to the existing cluster. At each iteration a new particle is added to one of the closest neighboring sites of the existing cluster. Although the centre of Eden cluster is almost uniformly occupied by particles but its border has fractal properties therefore it is an appealing model for tumor border. so it is best described using fractal phenomenon[9] and even it can be used to make better understanding of tumor and characterize it on this basis[5, 14].

II. ALGORITHMIC BACKGROUND

Statistical Growth Processes(Various Eden growth models): Eden growth model is very efficient model for tumor growth. We are applying eden model in three ways; first we are using uniform probability distribution model based random numbers. In uniform pobability distribution random numbers, the probabiltiy of each event is equal. In this model, we have taken three parameters as input arguments: seed_point, cell_size, and no. of iterations. Seed_point indicates the origin point from where the growth starts. In our case the seed points is[0 0]. Cell_size is 1. and no of iterations is 1000. Our code named eden1 is based on following algorithm of eden1.

Algorithm for Eden1 tumor growth model:
1- Input the three parameters such as seed_pt, cell_size, and iter_no into the our eden1 function.
2- Calculate neighbor_list by using following formula:
neighbor_list = [x(1) + cell_size, y(1);x(1), y(1) + cell_size; x(1) - cell_size, y(1); x(1), y(1) - cell_size];
where x(1)and y(1) are seed points.
3- Assign x(1)and y(1)to eden_list.
Repeat step 4 to step 9 up to the iter_no.
4 calculate the size of Neighbor_list.
5- Generate random numbers using r=rand(1,row1).
6- Find the indices for which the value of r is max.
7- Consider this max index of neighbor_list as new_point and assign it as new coordinates xn and yn.
8- Add the new_point to eden_list and find the size of eden_list.

9- Calculate new_neighbors and update neighbor_list with new_neighbors.
10- Plot the growth of eden growth model.
11- Show the simulated binary image.

In Eden2 model, we are using Normal probability based random numbers. In this model, we have taken three parameters as input arguments: seed_point, cell_size, and no. of iterations. Seed_point indicates the origin point from where the growth starts. In our case the seed points is[0 0]. Cell_size is 1. and no of iterations is 1000. Our algorithm named eden2 follows the following rule.

Algorithm for eden2 tumor growth model:
1- Input the three parameters such as seed_pt, cell_size, and iter_no into the our eden2 function.
2- Calculate neighbor_list by using following formula:
neighbor_list = [x(1) + cell_size, y(1);x(1), y(1) + cell_size; x(1) - cell_size, y(1); x(1), y(1) - cell_size];
where x(1)and y(1) are seed points.
3- Assign x(1)and y(1)to eden_list.
Repeat step 4 to step 9 up to the iter_no.
4 calculate the size of Neighbor_list.
5- Generate random numbers using r=randn(1,row1).
6- Find the indices for which the value of r is max.
7- Consider this max index of neighbor_list as new_point and assign it as new coordinates xn and yn.
8- Add the new_point to eden_list and find the size of eden_list.
9- Calculate new_neighbors and update neighbor_list with new_neighbors.
10- Plot the growth of eden growth model.
11- Show the simulated binary image.

In eden3 model,we are using Exponential decay Probability based random numbers. this model, we have taken three parameters as input arguments: seed_point, cell_size, and no. of iterations. Seed_point indicates the origin point from where the growth starts. In our case the seed points is[0 0]. Cell_size is 1. and no of iterations is 1000. Our algorithm named eden3 follows the following rule.

Algorithm for eden3 tumor growth model:
1- Input the three parameters such as seed_pt, cell_size, and iter_no into the our eden1 function.
2- Calculate neighbor_list by using following formula:
neighbor_list = [x(1) + cell_size, y(1);x(1), y(1) + cell_size; x(1) - cell_size, y(1); x(1), y(1) - cell_size];
where x(1)and y(1) are seed points.
3- Assign x(1)and y(1)to eden_list.
Repeat step 4 to step 9 up to the iter_no.
4 calculate the size of Neighbor_list.
5- Generate random numbers using r = exprnd(0.5,1,row1).
6- Find the indices for which the value of r is max.
7- Consider this max index of neighbor_list as new_point and assign it as new coordinates xn and yn.
8- Add the new_point to eden_list and find the size of eden_list.
9- Calculate new_neighbors and update neighbor_list with new_neighbors.
10- Plot the growth of eden growth model.
11- Show the simulated binary image.

III. MODIFIED EDEN MODEL FOR BETTER EFFICIENCY

In this model we have applied the proposed simulation techniques (different probability based random numbers) to grow brain tumor. As we know not much reference is available directly on the topic. In fact, gathering adequate knowledge about the actual physical description of a brain tumor and its distinguishing features is in itself a pretty tedious task. The design consists of three major modules - The features extraction from brain tumor, the simulation of tumor growth and finding matching between these images. The aim of this work is to develop a system which characterizes the brain tumor with the help of simulation parameters. Here we know that simulation parameters [15] are very important to us. Therefore, we are trying to develop better simulation techniques. For the same we designed new Eden growth model for each probability based random numbers.

By applying our new and modified eden model , an effiecient growth pattern is generated. By analyzing that pattern we can say that it is better than the previous simple eden model. Application of new and modified eden model on the data obtained from simple eden model produces better growth pattern[7,8]. The growth pattern obtained from new and modified model represents better simulated results for tumor growth. In the new eden model, we have taken these parameters such as eden_list, neighbor_list, cell_size and no of iterations. All the parameters mentioned above are provided as input to new eden model i.e. new_eden function. New and modified eden model named as new_eden produces the better growth pattern as compared with simple eden model. Algorithm of new and modified model is given by

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 funtion.
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.

IV. RESULT AND DISCUSSION

We applied our novel Simulation technique to grow tumor. Three different Eden growth model following different probability based random numbers shows the feature values for simulated tumor corresponding to Figure1, Figure2 and Figure3 respectively.

We have executed our code on 10 different random numbers. Following 10 different growth patterns are formed shown in a image. We can see that all the pattern are showing irregular growth. Figure generated for Eden clusters following Uniform Probability based random numbers are as following.

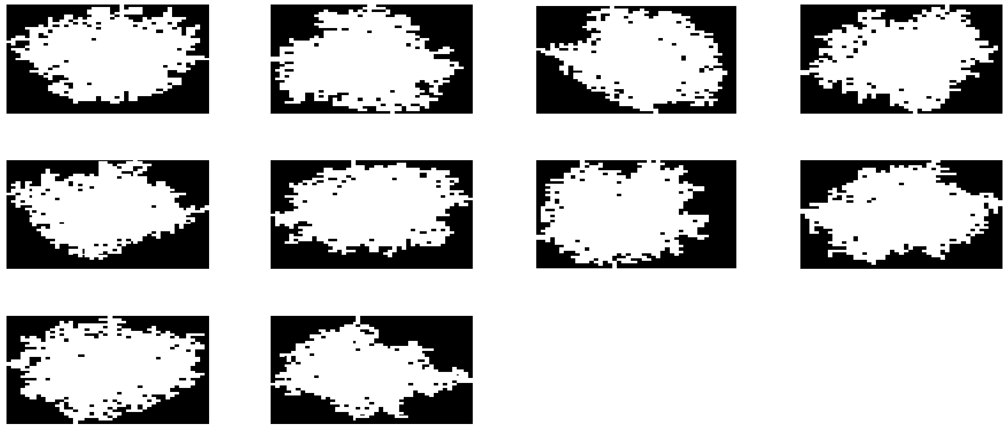

Figure1:Eden1 growth model

Eden2 produces the following images as result by taking the above three value as input argument. We have executed our code on 10 different random numbers. Following 10 different growth patterns are formed shown in a image. We can see that all the pattern are showing irregular growth. Figure generated for Eden clusters following Normal Probability based random numbers are as follows.

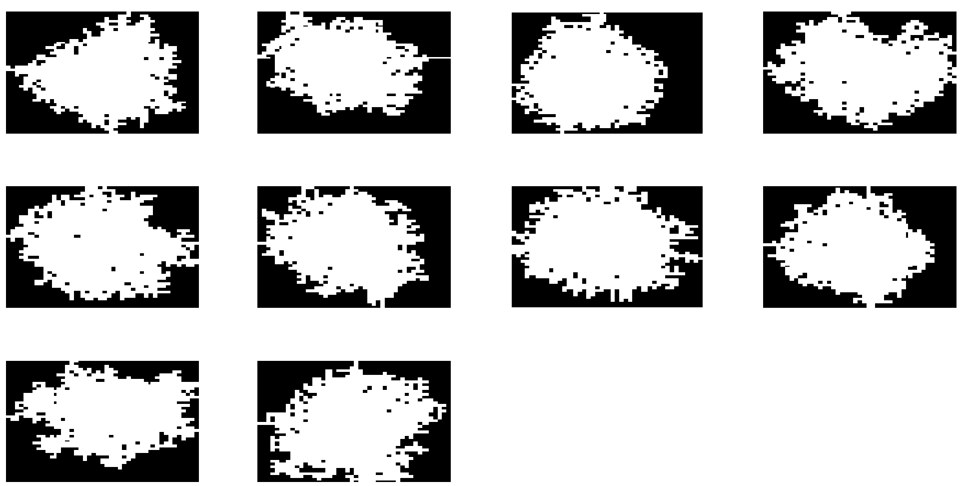

Figure2: Eden2 growth model

Eden3 produces the following images as result by taking the above three value as input argument. We have executed our code on 10 different random numbers. Following 10 different growth patterns are formed shown in a image. We can see that all the pattern are showing irregular growth. Figure generated for Eden clusters following Exponential decay Probability based random numbers.

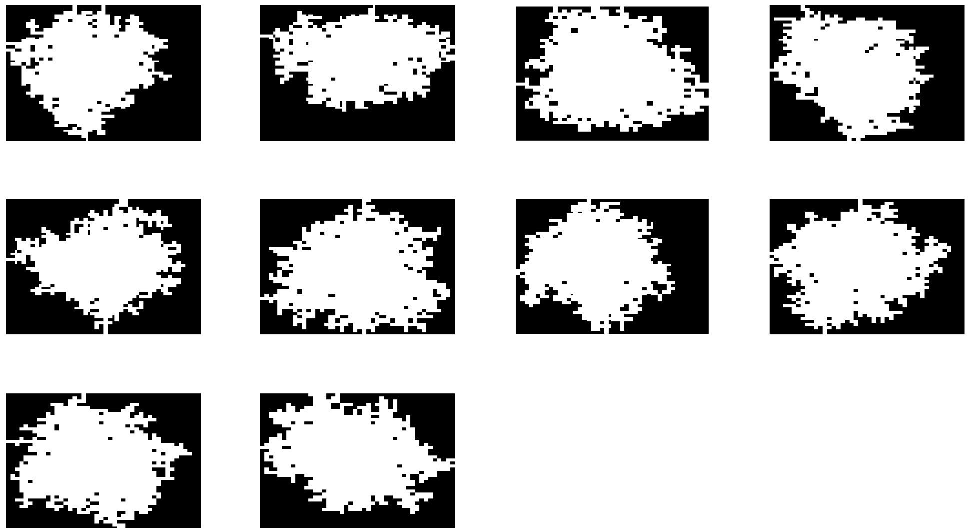

Figure3: Eden3 clusters

By visualizing the figures generated after applying various types of growth model, different simulated image for tumor growh is being produced and describing us the process of tumor growth. Initially the simulated images are produced by applying simple eden model of 1000 iterations. Since we are using 1000 iterations for producing the images. We can say the tumor is growing in linear fashion. At each iteration, one neighbor is being added to eden_list. Growth pattern is increasing one by one. From the above growth pattern, we can say that it is following arithmetic progression(AP). It is following linear growth pattern. In mathematical form, it can be represented as Ni+1=ni+1. to make our growth model more efficient , we have developed new eden model. which produces the better result as compared with simple eden model. from the results achieved from figure 4 and figure5, we can say that new eden model is more efficient.

We can see the results individually in different – different probability distribution functions as following.

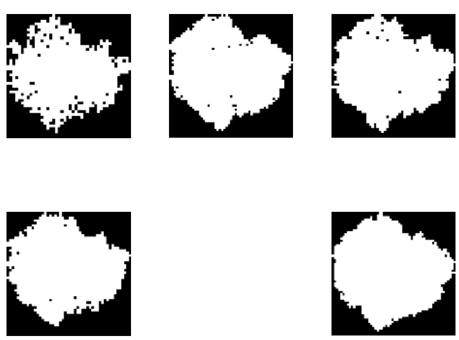

Figure4:Simple Eden and modified eden clusters

In the above figure, First cluster is formed from 1000 iteration of eden model (Uniform probability).this cluster is representing the simulation of tumor growth. In the second cluster, new and modified eden model is applied on the first cluster with 5 iterations. From the results we can see, it is better than the first cluster. The same process we adopted for generating the third and fourth cluster in the fifth cluster, 10 iterations of new_eden11 is applied on the first cluster. The result obtained in the fifth cluster is clearly showing that it is the better simulated image. From the above experiment, we can say that more the no. of iterations , better the growth pattern.

Brain tumor simulation is done by applying different probability based random numbers applied in Eden Algorithm which is based on well known principle of biological growth. Simulated tumor image shows better growth pattern.

This will be validated by extracting similar parameter features as that of the original brain tumor MRI images. Brain tumor simulation [12] is done in order to characterize the brain tumors depending on the value of their characteristic feature. This work gives us an understanding of what actually is the growth mechanism of the brain tumors inside the human body [13].

V. CONCLUSION

A new method to characterize brain tumor with help of simulation technique has been proposed. The specific properties of the image without preprocessing are produced , it is give the better grown cluster. 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.

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