Visualization of Adaptive, Nonuniform 3D data for Tumor Growth

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Recently, it has been shown that most of the solid tumors are composed of different cells species that are in different stages of development and a tiny subpopulation of the tumor cells is responsible for the formation, growth and recurrence of the tumor. Computational simulation for solid tumor growth is essential for understanding the spatial distribution and the volume fraction of these species, which lead to more effective therapeutic interventions. In addition to the traditional aspects of this research, such as modeling and algorithm development, the interpretation and presentation of the data to convey the information contained in the huge, sparse and complex data through the means of graphics is of vital importance, especially in this multidisciplinary research where mathematicians, computer scientists and biologists are working together.

1 Visualization of solid tumor growth

We visualized data obtained from numerical simulation of solid tumor growth. The left panel of Figure 1 shows the 3D distribution of different cell species in a tumor as well as branching and finger formation, which is characteristic of aggressive tumors. The tumor is composed of heterogeneous cell populations with clusters of stem cells appearing at the tumor boundary (shown in green), the transient amplifying cells that are further specialized (shown in blue) and terminally differentiated cells (shown in red). The stem cells give rise to transient amplifying cells. Transient amplifying cells are capable of dividing and producing new fully differentiated cells. The surface of the tumor is depicted in light brown. The top surface of the tumor is removed to show the internal spatial distribution of different species.

2 How did we do it

The simulation of tumor growth is produced using a previously published multispecies continuum model that simulates the spatiotemporal dynamics of cell lineages in solid tumors. The model accounts for protein signaling factors produced by cells in the lineages, and nutrients supplied by the microenvironment. The analysis and presentation of the simulation results posed several challenges. For instance, the simulation requires adaptive and non-uniform mesh to minimize the computational cost, as the right panel of Figure 1 indicates. Further, to reflect the spatial distribution and the volume fraction of several species we need to combine several different density data together. Also the simulation generates complicated sparse data at a large scale, which requires fast data processing and rendering. With traditional tools used in academia community such as Matlab, these challenges are poorly handled.

In this project we constructed a program in python which reads the information from simulation data and stores it in several "patches". For instance, each "box" in the right panel of Figure 1 represents one such patch. Next we transfer these paths into more capable graphic packages, such as blender. The flexibility of these packages allows us to present the data in more engaging and integrated way. As shown in the left panel of Figure 1 the spatial distribution of three different cell species and the shape of the resulting tumor are presented together, which provides much insight. We also use the voxel format instead of point clouds, which improved the efficiency significantly. Further, this program is capable of handling large scale data and can be extended to parallel implementation.

3 Result and future plan

Currently our program provides good visualization of numerical simulation for tumor with data as large as several gigabytes. These results in turn help the further study of the model. In the future we want to standardize this program so it can be used in other fields such as materials science and physics, which pose similar demands in visualization. Also we will extend this to the data with even larger scale with the help of a parallel implementation.

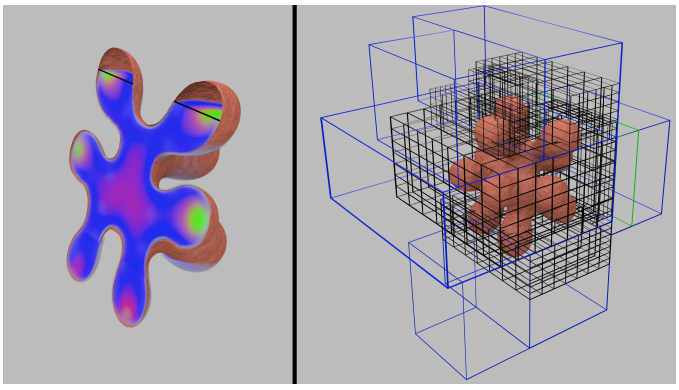

Figure 1. The numerical simulation of solid tumor growth in 3D on non-uniform mesh.