Cellular Potts model assignments

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1 Cell sorting

In this assignment you will work with the Morpheus example **CellSorting_2D.xml**. As discussed in class, it reproduces the original cellular Potts model formulation from reference [2]. The goal here is to run a parameter sweep with Morpheus that displays a variety of cell sorting configurations depending of the contact energies of the two cell types, as shown in reference [1]. For that, we can define the surface tension between two different cell types τ_1, τ_2 as:

$$\gamma_{\tau_1,\tau_2} = J_{\tau_1,\tau_2} + \frac{J_{\tau_1,\tau_1} + J_{\tau_2,\tau_2}}{2}, \tag{1}$$

which enable us to determine whether contact energies favor homotypic ($\gamma_{\tau_1,\tau_2} > 0$) or heterotypic ($\gamma_{\tau_1,\tau_2} < 0$) cell bonds. For instance, if we use the subindex m for the medium and y and r for yellow and red cells respectively, the following cell sorting configurations should be obtained depending on the specified surface tensions:

- Simple cell sorting ($\gamma_{y,r} > 0$, $\gamma_{y,m} = \gamma_{r,m} > 0$)
- Engulfment of red cells by yellow cells ($\gamma_{y,r} > 0$, $\gamma_{r,m} > \gamma_{y,m} > 0$)
- Mosaic cell ordering ($\gamma_{y,r} < 0$, $\gamma_{r,m} > 0$, $\gamma_{y,m} > 0$)
- Engulfment of yellow cells by red cells ($\gamma_{y,r} > 0$,$\gamma_{y,m} > \gamma_{r,m} > 0$)

Design a parameter sweep for two of the contact energies to reproduce all those patterns and possible transitions between them. When the sweep is finished, display all the results together using the table plot functionality of Morpheus in the ParamSweep section.

Tips:

(1) Use the same initial conditions for 100 cells used in CellSorting_2D.xml: 50 cells of each type distributed at random in a circle at the center of the lattice.
(2) You might want to increase the parameter Temperature slightly to facilitate cell patterning in shorter times.

2 Tumor growth

In this assignment you have to improve the simple tissue growth model that we built in the class (see file **tumor_growth.xml**). In that model we coupled a simple ODE model for the cell cycle to a classical cellular Potts model with only one cell type and we added a cell division plugin. If you let the simulation to run long enough, it would fill the entire lattice with cells. At that point, there is no space for cells to grow to their target area after each cell division but they would continue dividing and becoming smaller and smaller. Your task is to correct that behaviour in the model by allowing cells to divide only when they are 90% of their target area.

Can you think in other possible changes to this simple model that would make it more realistic to model tumor growth?

3 Networks

The simulation shown in the movie **networks.mp4** corresponds to the classical cellular Potts model from reference [2] plus a couple of very simple extra mechanisms. Can you guess from the movie what are those extra mechanisms?

References

[1] James A Glazier and François Graner. Simulation of the differential adhesion driven rearrangement of biological cells. *Physical Review E*, 47(3):2128, 1993.

[2] François Graner and James A Glazier. Simulation of biological cell sorting using a two-dimensional extended potts model. *Physical review letters*, 69(13):2013, 1992.