Feng, Jian, “Tissue Growth in 3-D: A New Computational Model that Integrates Cell Heterogeneity and Diffusional Limitations and its Parallel Implementation”

Advisor: P. Markenscoff

We present a new computational model that can be used in the study of tissue growth and wound healing processes. It consists of a discrete cellular automata (CA) model that governs the proliferation, migration and death of heterogeneous populations of cells, and a continuous PDE model that describes the convection, diffusion, and consumption of nutrients and/or growth factors (GFs) inside the tissue scaffold. The domain of the PDE model is mapped to the domain of the CA model such that at any particular time step, the local concentrations of nutrients/GFs at every cell site of the CA domain can be uniquely determined by solving a transient, three-dimensional PDE. Then the obtained concentration profile inside the tissue takes part in modulating cell functions through a series of intracellular processes. In our model, each cell population has its own proliferation, migration and death characteristics, as well as different metabolic properties such as the consumption rate of nutrients or growth factors. Our study suggests that under the diffusional limitations of nutrients/GFs, cell heterogeneity can have significant impact on the growth rate and pattern of the tissue.

Two different implementations of the model were developed on high performance computers. The NUT version considers nutrients (e.g., glucose) only and uses a static load balancing (SLB) scheme; the MGF version takes into account mitogenic growth factors only and employs a new dynamic load balancing (DLB) scheme. Performance analysis showed high speedup and excellent scalability for both implementations. For the MGF version, our results indicate that the DLB scheme resulted in better performance than the SLB scheme.