15th International Symposium on Computer Methods in Biomechanics and Biomedical Engineering
and
3rd Conference on Imaging and Visualization
CMBBE 2018
P. R. Fernandes and J. M. Tavares (Editors)

Abstract ID-124

HYBRID CELL-CENTRED/VERTEX MODEL FOR MULTICELLULAR SYSTEMS

Payman Mosaffa, Jose Muñoz, Antonio Rodríguez-Ferran

Polytecnic University of Catalonia, Spain
payman.mosaffa@upc.edu, j.munoz@upc.edu, antonio.rodriguez-ferran@upc.edu

Keywords: cell-centred, vertex model, equilibrium-preserving mapping, biomechanics, wound healing, tissue

Summary: We present a hybrid cell-centred/vertex approach to simulate the mechanics of cellular monolayers undergoing cell reorganisation. Cell centres are represented by a triangular nodal network, while the cell boundaries are formed by an associated vertex network. The two networks are coupled through a kinematic constraint, which we allow to relax progressively. This approach allows to independently controlling the material properties of the cell boundaries and the cell cytoplasm [1].

The method resorts to a rheological law that is based on an evolution law of the resting length [2,3]. This evolution is controlled through a material parameter that we call the remodelling rate and that mimics viscous effects. When the remodelling is high, the tissue relaxes and adapts its reference free configuration rapidly, while for very low values of a purely elastic response is recovered.

Cell-cell connectivity changes due to cell reorganisation or remodelling events are also simulated. These situations are handled by resorting to an Equilibrium-Preserving Mapping (EPM) on the new connectivity, which computes a new set of resting lengths that preserve nodal and vertex equilibrium [1]. The map aims to smooth the force jumps between connectivity changes.

The proposed technique enables to recover fully vertex or fully cell-centred models in a seamless manner by modifying a numerical parameter of the model. The properties of the model are illustrated by simulating monolayers subjected to an imposed extension and during a wound healing process [1]. The evolution of forces and the EPM are analysed during the remodelling events.

References

[1]P Mosaffa et al., Hybrid cell-centred/vertex model for multicellular systems with equilibrium-preserving remodeling. Int. J. Num. Meth. Biomed. Eng, 2017 (In press).

[2] K Doubrovinski et al., Measurement of cortical elasticity in Drosophila melanogaster embryos using ferrofluids. Proc. Nat. Acad. Sci. USA, 114 (5):1051–1056, 2017.

[3] J J Muñoz & S Albo, Physiology-based model of cell viscoelasticity. Phys. Rev. E, 88(012708), 2013.