Coupling of a cell migration model with an (N)SPH substrate to investigate dynamic generation of cellular tractions

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ABSTRACT

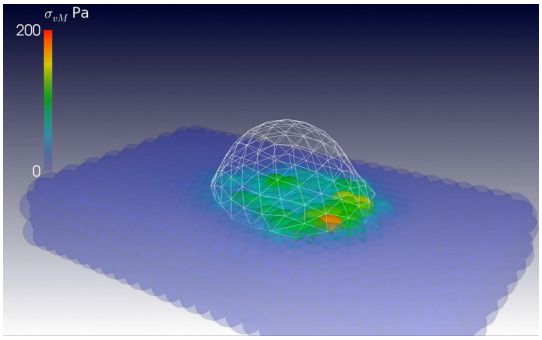

Figure 1: Cell migrating to the right on a visco-elastic NSPH substrate. Von Mises stress is shown in substrate colour; highest stresses appear under the lamellipodium in the front.

Cell migration is crucial for tissue development, maintenance and repair. To migrate, cells apply traction on the extra-cellular matrix (ECM) and degrade it. At the same time, the response of the ECM is an important cue for the cell to modulate mechanotransduction processes.

To investigate cell-ECM interaction in the context of active spreading and migration, a previously developed deformable cell model [1] has been extended by (amongst others) including a protrusive pressure at the leading edge of the cell. In this model, the membrane/actin cortex of the cell is discretized into deformable rounded triangles, over which contact pressures including adhesion are integrated between the cell and the ECM. The matrix represents a typical substitute ECM in *in vitro* experiments that is continuous at the cellular level and has tunable physical and mechanical properties. To be able to model the possibly large deformations and degradation of this hydrogel, we chose the Non-inertial, Smoothed-Particle Hydrodynamics (NSPH) [2] method to avoid frequent re-meshing that is typically required in finite element methods.

We will discuss the extent to which this method can capture typical hydrogel properties by comparing with FEM simulations of a simplified system. In a second step, we will highlight the effects of hydrogel properties as well as the properties of the hydrogel-cell interaction on active spreading and migration of the deformable cell. In particular, the model is able to capture stress magnitudes and distributions which correspond to typical traction force microscopy results for migratory epithelial cells, see Figure 1.

REFERENCES

[1] Odenthal, T., Smeets, B., et al. (2013). Analysis of initial cell spreading using mechanistic contact formulations for a deformable cell model. *PLoS Computational Biology, 9* (10), e1003267.

[2] Van Liedekerke, P., et al. (2013). Solving microscopic flow problems using Stokes equations in SPH. *Comp. Phys. Comm., 184* (7), 1686-1696.