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Upscaling between an agent-based model (smoothed particle approach) and a continuum-based model for wound contractions

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Deep tissue injury often results in contraction of skin due to mechanical pulling forces exerted by skin cells (fibroblasts) in the dermal layer. If contractions are morbid, then they are referred to as contractures. Contractures cause disabilities to patients, by, for instance, loss of mobility of a joint. By the use of modeling, we aim at understanding the mechanisms behind the formation of a contracture and at predicting which wound is likely to develop a contracture and which treatments can be employed in order to minimize the likelihood of a contracture. In most of our work, we used the immerse boundary approach based on a superposition of Dirac Delta functions to describe the forces exerted by individual skin cells, which results in a finite element solution that is not in H1. In [1, 2], we developed the smoothed particle approach as a replacement of the immersed boundary approach to improve the accuracy of the solution.

The smoothed particle approach is categorized as agent-based model, in which cells are considered as individuals. This class of models has the advantage of investigating the cellular activities of every single cell. Furthermore, for this modelling class, it is more straightforward to deduce parameter values from in vitro or in vivo experiments. However, once the number of cells is in the order of thousands and the wound scale is large (like centimeter square), these models become too expensive from a computational perspective. For the larger scales, continuum-based models are used. These models do not treat cells as separate entities, but treat cell behavior by the use of cell densities, which represent numbers of cells per unit volume. The resulting partial differential equations are easier to solve in terms of computational power.

We investigated the connections and consistency between these two types of models, regarding the momentum balance equation, which is used to describe the forces exerted by cells on the extracellular matrix (ECM) causing the deformation of the substrate. In one dimension, we establish the consistency between these approaches in both analytical solutions and finite-element method solutions. In the multi-dimensional case, we have only computationally shown the consistency between the continuum-based and agent-based models.

Time Block Preference

Time Block B (14:00-17:00 CET)

References

[1] Q. Peng and F. Vermolen. Numerical methods to solve elasticity problems with point sources. Reports of the Delft Institute of Applied Mathematics, Delft University, the Netherlands, 1389-6520(19-02), 2019.
[2] Q. Peng and F. Vermolen. Point forces and their alternatives in cell-based models for skin contraction. Reports of the Delft Institute of Applied Mathematics, Delft University, the Netherlands, 1389-6520(19-03), 2019.

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Primary authors: PENG, Qiyao (Delft University of Technology); VERMOLEN, Fred (Hasselt University)

Presenter: PENG, Qiyao (Delft University of Technology)

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