Cell mechanics analysis through physically-constrained optical flow and optimal control

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Cell motility is a key factor for the pathogenicity of most parasites. We aim at combining computational imaging and physics modeling to improve the understanding of parasites' capacity to protrude pseudopods and generate whole-cell movements. We analyzed microscopy sequences of the parasite E. histolytic (amoeba) where the actin-rich cytoskeletal structures were labeled with fluorescent markers. We modeled amoeba as active viscous fluids, so that their movement can be characterized by flow-mechanics quantities, such as local displacements, internal forces and pressure. We used an image analysis method augmented by a flow mechanics model, namely the optical flow method constrained by the Stokes equations that define the dynamics of a fluid that is incompressible, homogeneous and viscous. The system can then be set as a variational constrained-minimization problem. It is discretized with mixed finite elements and computational fluid dynamics methods, and solved using techniques from optimal control theory. Dense maps of the physical quantities can then be estimated. We will present and discuss results that reveal mechanisms used by amoeba during locomotion.

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