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Ameboid Cell Motility: A Model and Inverse Problem, with an Application to Live Cell Imaging Data

ABSTRACT

In this article a mathematical model for ameboid cell movement is developed using a spring-dashpot system with Newtonian dynamics. The model is based on the facts that the cytoskeleton plays a primary role for cell motility and that the cytoplasm is viscoelastic.

Based on the model, the inverse problem can be posed: if a structure like a spring--dashpot system is embedded into the living cell, what kind of characteristic properties must the structure have in order to reproduce a given movement of the cell? This inverse problem is the primary topic of this paper.

On one side the model mimics some features of the movement, and on the other side, the solution to the inverse problem provides model parameters that give some insight, principally into the mechanical aspect, but also, through qualitative reasoning, into biophysical aspects of the cell. Moreover, this analysis can be done locally or globally and in different media by using the simplest possible information: positions of the cell and nuclear membranes.

It is shown that the model and solution to the inverse problem for simulated data sets are highly accurate. An application to a set of live cell imaging data obtained from human brain tumor cells (U87-MG human glioblastoma cell line) then provides an example of the efficiency of the model, through the solution of its inverse problem, as a way of understanding experimental data.