A coupled PDE-ODE model for short range dynamics on microfluidic chips

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Abstract

The organs-on-chip approach (OOC) represents a novel instrument to investigate how different cells migrate, interact and respond to signals emanated from the micro-environment. Thus, confining cells on a well-defined domain allows experimentalists to have a major control on them.
In the late years OOC was employed to analyze how immune cells (ICs) migrate in presence of tumor cells (TCs), which were treated with chemotherapeutic agents and experiencing the process of immunogenic cell death. Although the use of chips can help to unravel most of the hidden facets of cells behaviors, some mechanisms remain unknown.
To provide a mathematical formulation of the problem, we introduce a hybrid system given by the coupling between a partial differential equation equipped with Robin inhomogeneous boundary conditions, which describes changes in the concentration of the chemoattractant and an ordinary differential equation to describe the motion for each ICs.
With the current model we are able to reproduce different possible scenarios, which depend on the number and the location of TCs and on the total amount of chemoattractant, related to a subarea of the chip, thus focusing on the short range dynamics.
To validate the model, we developed a specific calibration algorithm. The originality of our strategy consists in comparing the velocity fields produced by synthetic data with the velocity fields produced by the model solutions. To accomplish this, we interpolate the velocities of the cells at each time producing a velocity field surface and then costructing the objective function. To improve the strenght of our technique, we took into account also the functional given by the distances between ICs and TCs.
Our calibration algorithm is efficient in the case of synthetic data, thus it represents a first step in solving the calibration problem related to real data.

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