Particle based simulation of dense cellular flow and microswimmers in microvessels.

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Abstract

Cellular flow plays an important role in many physiological processes and pathologies in the organism. In microcirculation, the motion, deformation and hydrodynamic interaction of cells play a dominant role in the mechanics of blood flow, mass transport of chemical substances, organism defence through immune response, and blood-related diseases such as malaria and African trypanosome. The African trypanosome is a microswimmer with a unique morphology that migrates through the blood-brain barrier and causes a devastative sleeping sickness. To understand these processes, we need a detailed investigation under realistic conditions. Experimental techniques still encounter difficulties in high hematocrit (Hct) conditions owing to opaque images; it is also difficult to create complex networks of circular channels mimicking the in vivo microvasculature. To overcome these problems, we have developed large-scale simulation using particle base methods including Moving Particle Semi Implicit method (MPS) and Multi-Particle Collision Dynamics (MPC).

In the first part of this lecture, I will give an overview and a comparison of these simulation techniques. I will review modeling of the trypanosome, single cells and their suspension (blood). The implementation of boundary conditions and the coupling of the fluid to cell membrane will be explained on the basis of this approach. I will then present how to develop a highly scalable algorithm for parallel computing of these models on supercomputers.

In the second part, applications of the simulations to red- blood-cell deformations at dense cellular flow, spreading of fluid particles in blood flow, and swimming dynamics of the trypanosome will be discussed. These simulations can be used to investigate large scale complex hemodynamics includes the study of blood disease and the design of microfluidic devices for blood diagnosis.