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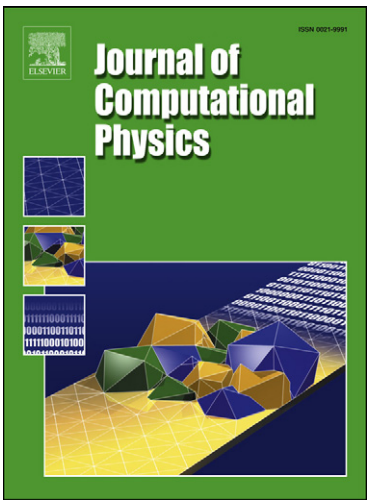

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A Fictitious Domain Method with a Hybrid Cell Model for Simulating Motion of Cells in Fluid Flow

Wenrui Hao* Zhiliang Xu† Chun Liu‡ Guang Lin§

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Abstract

In this study, we develop a hybrid model to represent membranes of biological cells and use the distributed-Lagrange-multiplier/fictitious-domain (DLM/FD) formulation for simulating the fluid/cell interactions. The hybrid model representing the cellular structure consists of a continuum representation of the lipid bilayer, from which the bending force is calculated through energetic variational approach, a discrete cytoskeleton model utilizing the worm-like chain to represent network filament, and area/volume constraints. For our computational scheme, a formally second-order accurate fractional step scheme is employed to decouple the entire system into three sub-systems: a fluid problem, a solid problem and a Lagrange multiplier problem. The flow problem is solved by the projection method; the solid problem based on the cell model is solved by a combination of level set method, ENO reconstruction, and the Newton method; and the Lagrange multiplier problem is solved by immerse boundary interpolation. The incompressibility of the material is implemented with the penalty function method. Numerical results compare favorably with previously reported numerical and experimental results, and show that our method is suited to the simulation of the cell motion in flow.

Keywords: fictitious domain method; Navier-Stokes flow; fluid-structure interaction; level set method; ENO reconstruction; elastic energy.

*Mathematical Biosciences Institute, The Ohio State University (hao.50@mbi.osu.edu, people.mbi.ohio-state.edu/hao.50).

†Department of Applied and Computational Mathematics and Statistics, University of Notre Dame, Notre Dame, IN 46556 (zxu2@nd.edu).

‡Department of Mathematics The Penn State University University Park, PA 16802 (liu@math.psu.edu).

§Department of Mathematics, School of Mechanical Engineering, Purdue University, West Lafayette, IN 47907 (guanglin@purdue.edu).