MINISYMPOSIUM

FREE BOUNDARY PROBLEMS IN MATHEMATICAL BIOLOGY

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Moving interface and free boundary problems arise in the modelling of a variety of biological phenomena such as tumour growth, cell motility, population dynamics and pattern formation. The models involve systems of nonlinear PDE and the analysis of such models is at the forefront of current research. Often analytical solutions are unavailable and state-of-the-art numerical methods are required for the simulation of the model equations.

The goal of this minisymposium is to foster the exchange of ideas by bringing together analysts, modellers and experts in scientific computing who share an interest in biological free boundary problems.

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ATTRACTIVE-REPULSIVE MODELS IN COLLECTIVE BEHAVIOR MODELS AND APPLICATIONS

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Keywords: Aggregation-diffusion, Cell adhesion, Pattern formation, Organogenesis.

We will discuss properties of solutions to aggregation-diffusion models appearing in many biological models such as cell adhesion, organogenesis and pattern formation. We will concentrate on typical behaviours encountered in systems of these equations assuming different interactions between species under a global volume constraint.

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NUMERICAL SIMULATION OF MEMBRANE MEDIATED PARTICLE CLUSTERING IN AN ELASTIC MODEL

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Keywords: Canham–Helfrich energy, Membrane deformation, Particles.

The aggregation of curvature-inducing particles plays a crucial role in various biological processes that involve the deformation of membranes, such as endo- and exocytosis. In some cases it is suggested that clustering of membrane particles is governed by the membrane's elastic properties, which leads to an interplay between particle-induced membrane deformations and membrane-driven particle movements. Continuum-discrete models for such a system usually lead to the problem of solving partial differential equations either on moving domains or with varying constraints. The literature indicates that the behavior of the resulting system significantly depends on the shape of the particles, which complicates the analytical solution and favors numerical approaches in order to gain insight into certain particle interactions.

In this talk we consider a Canham–Helfrich elasticity membrane model in Monge-gauge where the membrane-particle coupling is modeled through a finite number of boundary conditions. Within this setting we are able to prove differentiability of the particle interaction energy and propose a convergent scheme for efficient evaluation of the derivative which is also feasible for finite element discretizations of the membrane.

Our findings can directly be applied in order to derive a gradient method for investigating stationary particle configurations. Furthermore, the applied methods generalize to a wider range of problems, which may be helpful in the development of more efficient algorithms for exploring particle interactions in various other regimes.

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FREE AND MOVING BOUNDARY PROBLEMS IN CELL BIOLOGY

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Keywords: Receptor ligand interactions, Cell motility, Surface finite elements.

Free boundary problems arise very naturally in the modelling of problems in cell biology, for example in models for cell motility, receptor-ligand dynamics and cell signalling. Mathematical theory has an important role to play in establishing the well posedness of such models and thereby giving some concrete validity to inferences based on formal analyses and simulation of the model equations. On the other hand the biological motivation provides a rich seam of challenging problems which prompts the development of new mathematics. In this talk we shall discuss analytical aspects of some FBPs that are motivated by models from cell biology and their numerical simulation with finite element methods.

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BOUNDARY DOMAIN INTEGRAL METHODS FOR THE SOLUTION OF THE NAVIER - STOKES EQUATIONS.

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Joint work with Jorge Tiago (Department of Mathematics and its Applications, Instituto Superior Tecnico), Adelia Sequeira (Department of Mathematics and its Applications, Instituto Superior Tecnico)

Keyword: Boundary element method.

In the present work the velocity vorticity forumation of the Navier - Stokes for 2d and 3d dimensions is presented. The integral representation of the governing equations are derived and they are numerically solved by various integral domain based methods like meshless LBIE, Fast Multipole Method FMM and Boundary Element Method BEM. Details about the computation of integrals are discussed. The potentiality of each method is demonstrated with various examples of fluid flow problems.

References

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