

An Indian-Australian research partnership

Project Title: Numerical methods for free boundary problems in three dimensions with applications in biology

Project Number IMURA0606

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Mathematics

Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?

(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1. Advanced computational engineering, simulation and manufacture
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research

The research problem

Many phenomena in science and engineering can be modelled using partial differential equations (PDEs) defined on an unknown (and evolving) domain. This type of problem is commonly referred to as a free boundary problem. While numerical methods to solve free boundary problems in one dimension are well established, there is a need to develop appropriate numerical methods in higher dimensions.

In this project, novel numerical methods for free boundary problems in two and three dimensions will be developed using a finite element framework for the spatial discretization. We will test the newly developed methods by implementing them for the heat equation with a known boundary velocity profile in both two and three dimensions.

The overarching application for this study is the growth of a tumour in three dimensions. The tumour will be modelled as a multiphase material, containing cancer cells and extracellular fluid. The system of governing PDEs will include conservation equations for the cell and fluid volume fractions and the nutrients that supports growth, and equations of momentum conservation. The tumour will be defined on an evolving domain as the tumour grows, which will need to be solved for as part of the numerical scheme. We will apply the novel numerical methods developed to approximate the solution to the model of the growing tumour in three dimensions.

Project aims

This project aims to:

- (a) Develop novel numerical methods to solve free boundary problems in two and three dimensions.
- (b) Implement and test the methods in (a) to solve benchmark problems including the heat equation in two and three dimensions with a fixed boundary velocity profile.
- (c) Implement and apply the methods in (a) to a problem in biology, namely the growth in 3D of a tumour.

Expected outcomes

- (a) Development and implementation of novel methods to solve free boundary problems in two and three dimensions.
- (b) Numerical simulation of multiphase models of growing tumour in three dimensions, which has not previously been performed.
- (c) Quality international research publications;
- (d) Joint supervision of a Ph.D. student from India which will help to boost the research in Numerical Analysis and Mathematical Biology in the country;
- (e) Initiating collaborative research work between Monash University and IIT Bombay in the broad area of numerical analysis and mathematical biology

How will the project address the Goals of the above Themes?

We would be addressing the **Advanced computational engineering, simulation and manufacture** theme, by providing tangible progress in the direction of simulation techniques for free boundary problems in three dimensions. The techniques will be applied to a biological application.

Capabilities and Degrees Required

Candidates should

1. have a strong mathematical background;
2. have done courses in Partial Differential Equations and Numerical Analysis at the Masters level;
3. knowledge and aptitude in computer languages – like Matlab, Fortran90, C or C++ – is essential.

