IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	"Microfluidic mixing by collective motion ofactive particles"	
Project Number	**IMURA0624**	
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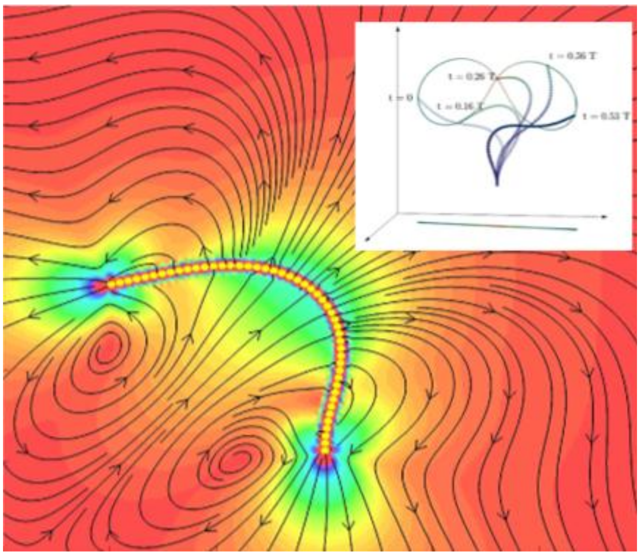
Research Academy Themes:

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
7. Humanities and Social Sciences

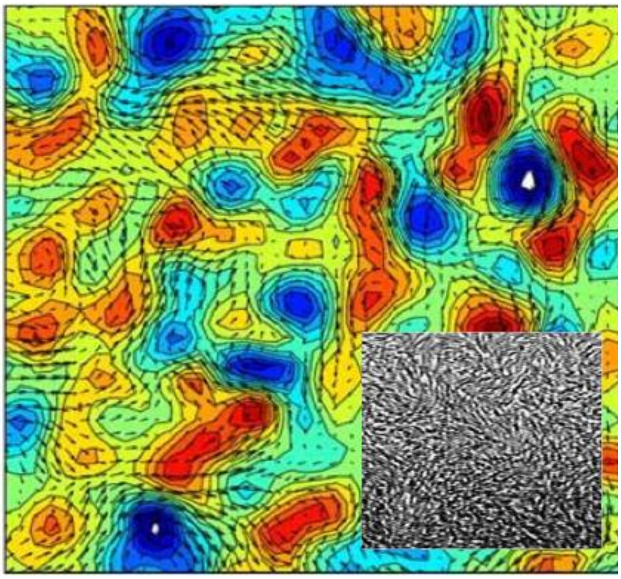
The problem: There is enormous interest today in shrinking devices to ever smaller scales. "Lab-on-chip" devicesare the holy grail in medical diagnostics, genetic screening and manipulation,contaminant detection, and even large-scale chemical manufacture and waste treatment. There are two majorstumbling blocks at present to realizing compact microfluidic devices.



An internally driven flexible microfilament can undergo wavy motions (inset) driving complex flows in the surrounding fluid. (Image source: Laskar et al., Sci. Rep., 2013)

In small volumes of fluids confined in microchannels,bringing chemicals together by *mixing*is a challenge. Friction imposed by the walls makes *pumping* difficult as well. If you walk into a typical microfluidics lab today, you will see that most of the desk space is taken up by the machinery required to achieve pumping and mixing: we have chips-in-labs, as opposed to labs-on-chips!

The solution: Biology has solved these problems long time ago. Many simple single-cell creatures use little filaments that constantly wave to pump the surrounding fluid around leadingto propulsion. Self-organized collective motion of these filaments is observed to drive complex flows to enhance mixing to access dissolved oxygen or fresh nutrients. In many bacterial and algal species, cells also collectively swim together to generate large scale flows in the surrounding fluid to achieve mixing and fluid transport.



The flow field in a simulation (inset: real bacteria) of a suspension of self-propelled particles looks like a turbulent flow field although the Reynolds number of any single particle is very small. (Image source: Cisneros et al., Exp. Fluids, 2007)

We are only now beginning to uncover the mechanisms underlying these fascinating systems. When microparticles or elastic are driven by internal mechanisms (for instance, by ATP-powered chemical reactions in cells), they generate flows that in turn affect the shapes or orientations of the particles themselves. Biological systems have evolved to take advantage of these interactions. Our goal in this project is to use computationsto study the collective motion of such micron-sized "active" particles and filaments and investigate the mixing caused that motion.

The outcomes: We hope to develop the ability to design and guide experiments to fabricate and test novel self-contained microfluidic mixers and pumps. The project will provide you with in-depth training in cutting-edge techniques for micro/nanofluidic simulations, and a springboard to an exciting research career in nanosciences, microfluidics, or biophysics.

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

As indicated in the description, the project is about computational fluid dynamics (CFD). We propose to use specialized particle-based simulation methods that can efficiently account for fluid-structure interactions and thermal noise at micro/nano scales. These simulations will lead to insight that could enable the development of novel microfluidic applications. The project thus addresses the goals of the theme of “advanced computational engineering, simulation and manufacture”.

Capabilities and Degrees Required

Essential requirements:

- Undergraduate degree or masters in physics or mechanical/ chemical engineering
- Interest in theory, mathematical modeling and computer simulations

Preferred:

- Experience in theory or mathematical modelingor computer simulations of physical phenomena

Potential Collaborators

RaghunathChelakkot, Physics, IIT Bombay
PrabhakarRanganathan, Mechanical & Aerospace Engineering, Monash University

Please provide a few key words relating to this project to make it easier for the students to apply.

Fluid mechanics, modeling, simulations, computational fluid dynamics (CFD), active matter