IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Physics Informed Deep Neural Network for Solid Mechanics - Application to Soft Biomaterials**	
Project Number	**IMURA0909**	
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IITB Department:	Department of Mechanical Engineering	

Research Clusters:

Research Themes:

1	*Material Science/Engineering (including Nano, Metallurgy)*	***1***	*Advanced computational engineering, simulation and manufacture*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*	2	*Infrastructure Engineering*
3	*Math, CFD, Modelling, Manufacturing*	3	*Clean Energy*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*	4	*Water*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*	5	*Nanotechnology*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*	6	*Biotechnology and Stem Cell Research*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*	7	*Humanities and social sciences*
8	*HSS, Design, Management*	8	Design

The research problem

Soft and stretchable materials can go through large and quick deformations. These materials find applications in smart biomedical devices e.g. soft robots for drug delivery. In some of the applications the soft materials need to maintain the shape after the actuation. The required shape-programmability can be achieved for soft materials with high coercivity. Such materials can not only go through large deformations but can also retain it even after the stimulating magnetic field is turned off. Nonlinear finite deformation has been studied for many decades. However finite deformation actuated by magnetic field is a much newer problem and has wide applications. In this project we intend to develop a numerical framework based on mechanics of a hard magnetic soft material in presence of magnetic field. The momentum balance and constitutive relations will be incorporated into a physics driven deep neural network. The idea is to make the network learn about solid mechanics and create a coupled numerical methods that is superior to standalone finite element method. We consider a Physics Informed-DNN approach in which the physical parameters of the finite element approximation of the PDE are DNNs and will be automatically calibrated using a minimisation of the mismatch between observable data and the PDE result.

Project aims

1. Develop constitutive framework for actuation of hard magnetic-soft material
2. Physics driven deep neural network based numerical algorithms for finite deformation – magnetic field coupled models and their implementation
3. Validation using test cases available in literature
4. Design use cases that be validated by experiments in subsequent projects

Expected outcomes

1. A constitutive framework for mechanics of magnetic actuation of soft material
2. A simulation tool for coupled finite strain-magnetic actuation

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

The project applies Advanced Computational Engineering for Biomedical applications. It falls in the category (1) and (6).

Potential RPC members from IITB and Monash

Tanmay Bhandakkar (expert in Elasticity, tbhanda@iitb.ac.in)
Ricardo Ruiz-Baier (expert in numerical methods for PDEs, ricardo.ruizbaier@monash.edu)

Capabilities and Degrees Required

An ideal candidate should have a BTech or BE or Master in Mechanical Engineering, Aerospace Engineering, Civil, Mathematics or Physics, with a strong inclination towards advanced mathematics, numerical methods, continuum mechanics, non-linear elasticity. Experience in at least two of the following three criteria is desired: 1. Background in mechanics of materials; 2. Expertise in numerical methods for PDEs (finite element methods); 3. Expertise in programming (Julia, Python, C, C++, Fortran, etc)

Potential Collaborators

Jerome Droniou (expert in numerical methods for PDEs, jerome.droniou@monash.edu)
Ricardo Ruiz-Baier (expert in numerical methods for PDEs, ricardo.ruizbaier@monash.edu)
Raghunath Chellakot (Soft Matter, raghu@phy.iitb.ac.in)
Neela Nataraj (Finite Element Method, neela@math.iitb.ac.in)
We will also look for collaborators in Chemical Engineering or Bio Sciences and Engineering for experimental validations.

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.

Computational Fluid Dynamics and Mechanics , Soft Matter, Soft Robots, Smart Biomaterials