Indian Institute of Science

Centre for BioSystems Science and Engineering

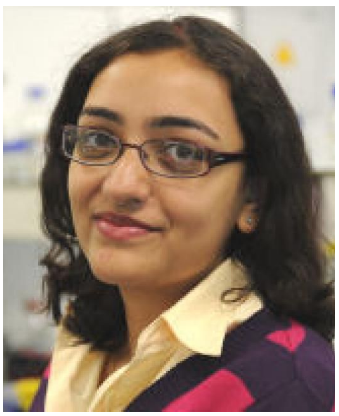
BSSE Seminar

28th October 2019 (Monday), 11:00 AM, CES Seminar Hall, 3rd floor, Biological Sciences Building

Multi-scale Modeling of the Heart: An Interdisciplinary Approach to Improving Cardiac Arrhythmia Management and Therapy

Dr. Rupamanjari Majumder
Max Planck Institute for Dynamics and Self Organization

ABOUT THE SPEAKER



Dr. Rupamanjari Majumder received her IntPhD degree from the Department of Physics, Indian Institute of Science, Bangalore, where she used numerical methods to study spiral and scroll wave dynamics in ionically and anatomically realistic mammalian cardiac tissue. She was the first researcher from India, to develop organ-level computer modeling of cardiac electrophysiology. For her postdoctoral research, she joined the laboratory of experimental cardiology, led by Dr. Daniel A. Pijnappels, in the Leiden University Medical Center (LUMC, the Netherlands). In early 2017, she got promoted to the position of Assistant Professor at LUMC, where she remained until March 2018, and then moved to Goettingen, Germany, for family reasons. During her time in Leiden, she worked closely with Prof. Alexander Panfilov (Ghent University, Belgium). Currently, she works as a postdoctoral researcher in the Department of Prof. Eberhard Bodenschatz, at the Max Planck Institute for Dynamics and Self Organization, in Goettingen. She is developing the state-of-the-art model for anatomically and electrophysiologically realistic human atria, that can be used to study thermal control of atrial fibrillation, the most common form of sustained arrhythmia, occurring in humans. Her vision is to develop a virtual diagnostic package, based on a complete, integrated model of the human heart, which considers cardiac electrophysiology, anatomy, mechanics and blood flow, with patient-specific personalization.

ABSTRACT

The heart is the most important organ in the human body. It pumps up to 7600 liters of blood, on a daily basis, throughout the lifetime of an average healthy individual. This efficiency is maintained by a complex coordination of five different biophysical machinery: electrophysiology, electromechanics, solid mechanics, haemodynamics and innervation, that work together to produce one of the most sophisticated electromechanical pumps in nature. If, however, an abnormality disrupts cardiac function even for a very short period of time, it can trigger the collapse of the entire circulatory system, thereby upsetting the body's state of equilibrium. Delays in medical intervention, of the order of several minutes, can then lead to sudden cardiac arrest, which is the largest cause of death in today's world. Thus understanding how the heart works is a crucial first step in the development of new treatment modalities for acute and chronic heart diseases, particularly, rhythm-related disorders: arrhythmias. Lethal cardiac arrhythmias, like atrial fibrillation, ventricular tachycardia and ventricular fibrillation, are associated with the occurrence of vortices of electrical activity in the heart. These vortices sustain themselves by continuously shedding, into the surrounding tissue, excitation waves that have the potential to stimulate the heart into rapid, repetitive and inefficient contraction. However, the mechanisms underlying the formation and decomposition of these lethal vortices, together with their spatiotemporal dynamics under different pathological conditions, remain poorly understood. I use an interdisciplinary, bottom-up approach, based on computer modeling and accompanying experiments, to study vortex dynamics in the heart, in the context of arrhythmias, at the cell, tissue and organ level. In this seminar, I will demonstrate how to construct a cardiac cell model based on whole cell patch clamp data (Majumder *et al.*, *PloS Comp Biol.*, 2016). I will extend this model to 2D, in combination with computational cardiac optogenetics to demonstrate the first universal method to exercise real-time spatiotemporal control over spiral wave dynamics (Majumder *et al.*, *eLife*, 2018; selected for *eLife Digest*). Finally, at the organ level, I will show preliminary results of an ongoing study on the use of thermal tools to control scroll wave dynamics in anatomically and electrophysiologically realistic human atria. These studies add a whole new dimension to cardiac research and medicine, by introducing concepts that can be exploited to treat arrhythmias, in a fast, non-invasive, and painless manner.