UNIVERSITÀ di VERONA | Dipartimento di INFORMATICA | Collegio Didattico di Matematica | Master Degree in Mathematics

The electrophysiology of excitable tissues: modeling and numerical simulations

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In the recent decades, the possibility to simulate complex problems in Biomedical sciences popularised the use of computational models in advanced clinical practice. Such models, known as *in silico*, are today a regular support for the investigative activity of medical doctors and life scientists, alongside the *in vivo* and *in vitro* experiments. Medical doctors can benefit from effective and reliable non-invasive, patient-specific, instruments to improve diagnosis and prognosis. In return, mathematical and numerical models can provide rigorous tools for quantitative analyses with a diagnostic and prognostic content, and patient specific simulations are made possible by integrating such models with data and medical images. Still, biomedical problems are extremely complex and challenging from the modeling viewpoint. Typically they are characterised by remarkable heterogeneities and multi-scale dynamics, both in space and time: a reliable predictive mathematical model should be able to soundly cope with these aspects.

A characterizing property of excitable cells is the ability to initiate an action potential (AP), a term used to indicate a sudden variation in the transmembrane potential, called spike, followed by a recovering of the resting condition after a refractory period, during which the cell cannot be excited. Action potentials feature different shapes and amplitudes characteristic of the different kind of excitable media to which the cells belong to: in the large muscle cells make it possible the simultaneous contraction of the whole cell. Action potentials propagate along preferential conduction pathways in the form of electrochemical waves that, in physiological conditions, keep the same shape and amplitude all along the entire neural, muscular or cardiac fiber.

This course aims at providing an introduction to the mathematical modeling of excitable tissues, with a focus on cardiac myocytes and neurons. Both the microscopic description of the electrophysiological activity at the cellular level and the description of its propagation at the macroscopic size of the tissue will be addressed. The course will cover the introduction to the equations and initial/boundary value problems relevant to the modeling, and the methodology for their numerical simulation. The challenges associated with the development of patient-specific modeling will also be discussed.

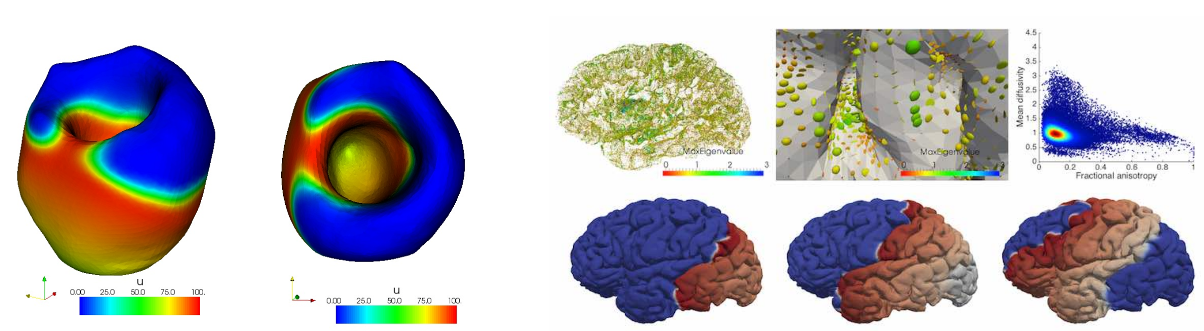

Figure 1: Left: action potential propagation on a ventricle reconstructed from CT scan. Right: propagation of the Cortical Spreading Depression on a brain geometry reconstructed from DTI-MRI.