III International Conference on Emerging Technologies in Computational Science for Industry,Sustainability and Innovation, M2P 2027
May 25-28, 2027, Terrasini (Sicily), Italy

RECENT ADVANCES IN COMPUTATIONAL ELECTROPHYSIOLOGY

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ABSTRACT

Computational electrophysiology enables the investigation of electrical activity in excitable tissues, from single-cell ion dynamics to organ-scale propagation, with applications spanning cardiac, neural, and other bioelectrical systems. Recent advances in mathematical modeling, high-performance computing and data-driven methods are enabling increasingly detailed and predictive simulations across spatial and temporal scales, from ion channels to single cells, tissues and whole organs. The underlying models are demanding: stiff systems of ordinary differential equations describing ionic dynamics are coupled with partial differential equations governing propagation at the tissue level, while their numerical solution must resolve steep, highly localized fronts over long time intervals.

This session brings together researchers working on the development, analysis, and application of computational methods for electrophysiology, with particular emphasis on methodological advances that bridge biophysical modeling, numerical simulation, and experimental data. The session focuses on the design and analysis of numerical solvers, their efficient implementation on large-scale computing architectures, and the integration of computational models with real data, where uncertainty quantification and machine learning are playing an increasingly central role. Recent developments in these directions are opening new possibilities for a range of applications, including digital twins, in silico trials, and model-based therapy planning. A further aim is to foster exchange between researchers developing new mathematical and computational methods and those working closely with experimental and clinical data. It is often from this interaction that the most relevant and challenging methodological questions emerge, leading to new computational approaches.