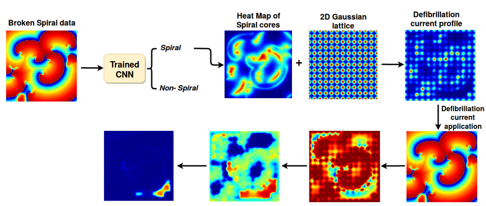
A Deep-learning method for detecting and terminating spiral waves in mathematical models for cardiac tissue

Mahesh Kumar Mulimani, Jaya Kumar Alageshan, Rahul Pandit

Department of Physics, Indian Institutte of Science
Bangalore, India

The development of low-amplitude defibrillation schemes, for the elimination pathological electrical waves of activation, in cardiac tissue, is a major challenge in the treatment of life-threatening cardiac arrhythmias. We combine the dataset generated from extensive direct numerical simulations (DNS) using mathematical models for cardiac tissue with a deep-learning method to construct a new defibrillation scheme to eliminate unbroken and broken spiral waves, which are the mathematical analogs of ventricular tachycardia and ventricular fibrillation. We use convolution neural network (CNN), where we train the CNN to distinguish spiral-wave patterns (S) from those that do not have spiral waves (NS). For the training, the dataset we use is $\simeq 25000$ different pseudocolor plots of the transmembrane potential V_m obtained from DNS of both two-variable and ionically realistic models for cardiac tissue.

We have checked that our trained CNN can, distinguish between patterns: with spirals, and patterns that do not have spirals.



The schematic figure showing defibrillation scheme developed using the trained CNN.

Next, we show how to generate a heat map of the broken spiral waves, which has high intensity in regions with spiral-wave cores; this heat map plays a central role in our new defibrillation scheme: We first show that a control (defibrillation) current with a two-dimensional (2D) Gaussian profile (with width $\sigma \simeq 75\%$ of linear size of our simulation domain) eliminates the spiral wave when we apply it exactly at the spiral core. We then demonstrate that the defibrillation-current profile, comprising of 2D Gaussians on a square lattice, whose amplitudes are proportional to the heat-map intensity at a given point in our simulation domain, eliminates broken spiral waves.