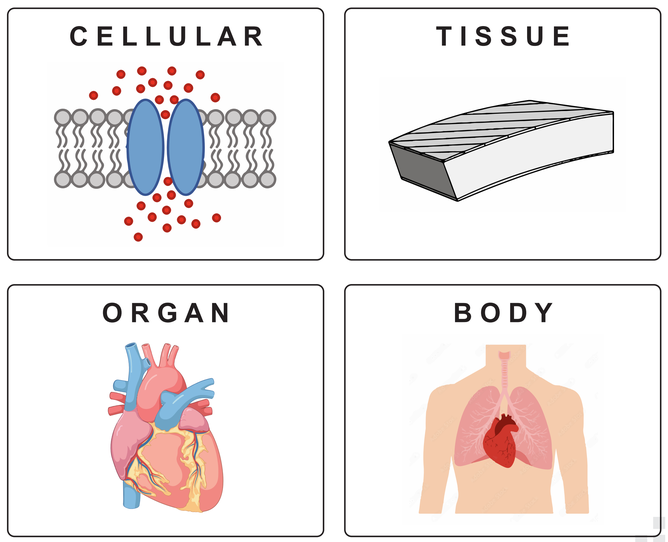
Uncertainity Quantification Applied to Cardiac Electrophysiology

Computational Electrocardiology Group
L. Rupp, A. Busatto, E. Paccione, B. Orkild, J. Bergquist, R. MacLeod, A. Narayan

Introduction

Uncertainty quantification (UQ) can be implemented in many applications, even baking cookies.

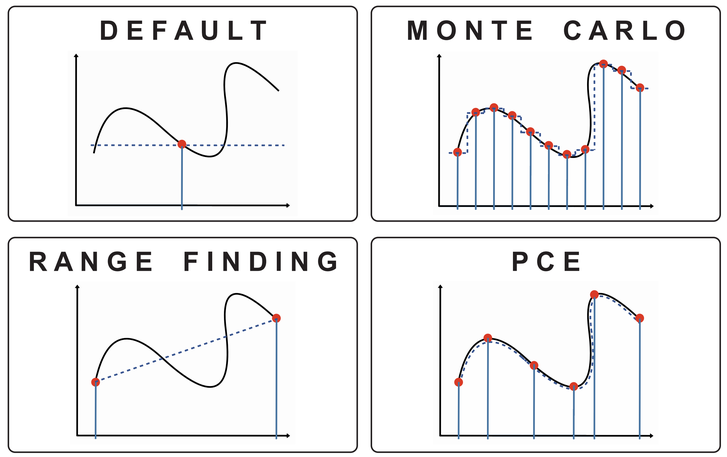
Cardiac digitial twins play an increasingly important role in the research, clinical and industrial communities. These models include information at different physiological levels including...



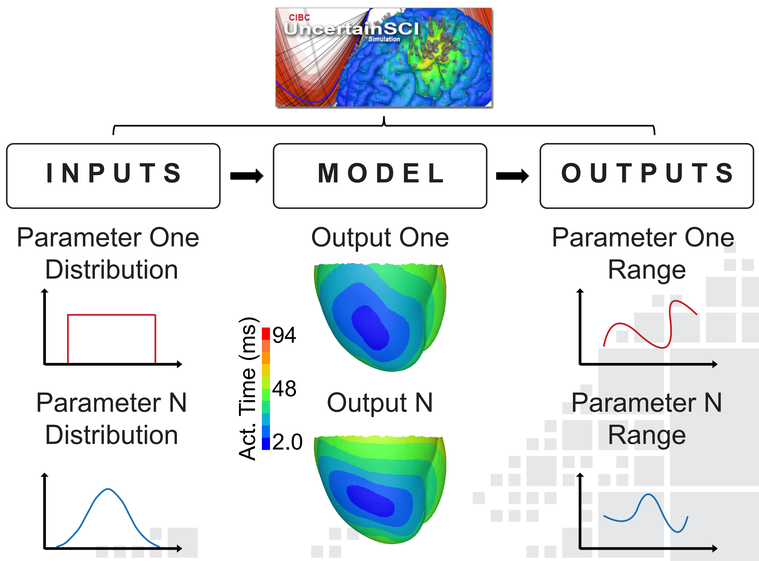
Each parameter contains uncertainity due to modeling errors, parameter errors, and natural patient variability. Such uncertainty can further propagate to the simulation output.

Methods

We can quantify parameter uncertainity using UQ from which we can sample the parameter space via...



Polynomial chaos expansion (PCE) allows the user to effectively capture the parameter space with minimal computational cost. Members at the SCI Institute developed UncertainSCI which implements PCE via Python.

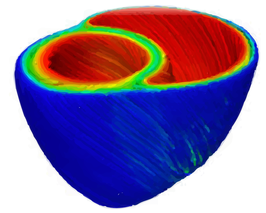


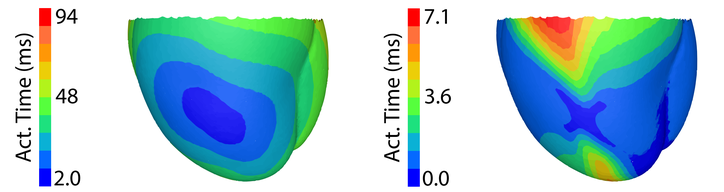
UncertainSCI calculates statistics such as mean, standard deviation (STD), quantiles, total/global sensitivities, and residuals.

Applications/Discussion

FIBER ORIENTATION

Cardiac tissue consists of fibers with smoothly varying orientations and excitation spreads preferentially along these fibers. We parameterized the fiber orientation via 2 parameters.

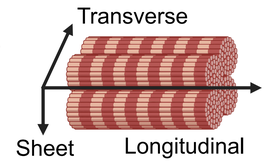


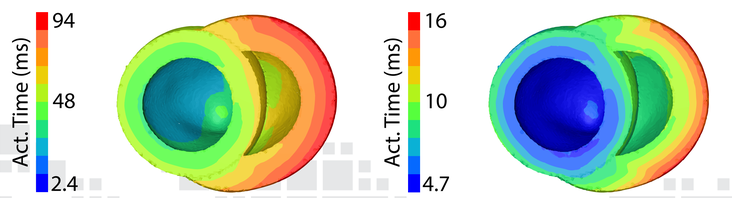


Our findings suggest that variability in fiber orientation has minimal impact on early sites of activation, but changes the overall spread of activation.

CONDUCTION VELOCITY

The spread of excitation in the heart is also a function of conduction velocity, which is the speed and direction of the electrical wavefront. We parameterized the conduction velocity via 6 parameters.





Our findings suggest that variability in conduction velocity results in a propagation of errors, such that as the distance from the stimulus increases, standard deviation increases.

UQ is a valuable tool that allows the user to quantify the impact each parameter has on the simulation output.

[1] A. Narayan, *Comput. Biol. Med.*, 152 (2023): 106407. [2] J. Tate, *JOSS*, 8.90 (2023): 4249. [3] J. Bergquist, *Physiol. Meas.*, 44.10 (2023): 105003.
[4] C. Berggren, *BMMB*, (2024). [5] A. Busatto, *2023 CinC*. Vol. 50. *IEEE*, 2023. [6] L. Rupp, *2023 CinC*. Vol. 50. *IEEE*, 2023.

THE UNIVERSITY OF UTAH
CEG
SCI
www.sci.utah.edu