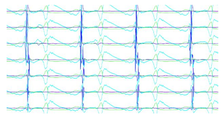
Personalized Heart Models for Safer and Faster Atrial Fibrillation Therapy

NSF CPS: Frontier: Medical Cyber-Physical Systems
Rahul Mangharam, University of Pennsylvania

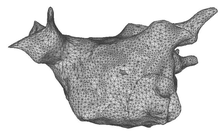
Patient electroanatomical mapping data is exported from catheter ablation operating room. These data are processed to extract the spatiotemporal electrical activations of the left atrium, then fed in a heart model for parameter optimization.

Electrode Locations

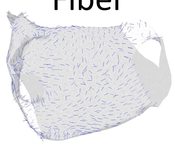
Electrograms



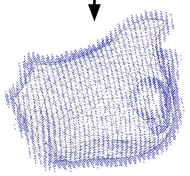
Atrium Mesh



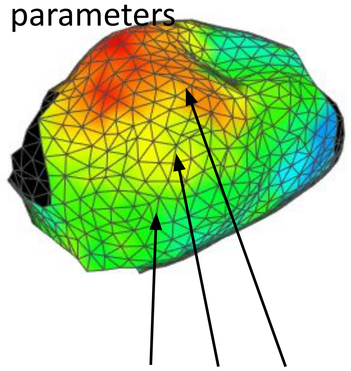
Fiber



Cartesian Grid



Every vertex has its own set of parameters

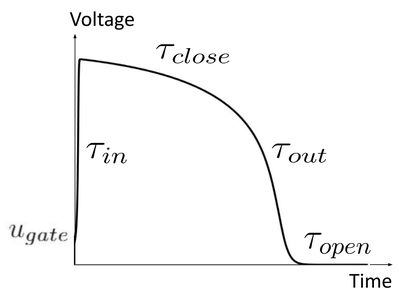


$$\frac{du}{dt} = \frac{hu^2(1-u)}{\tau_{in}} - \frac{u}{\tau_{out}} + J_{stimulus} + \nabla \cdot (D \nabla u)$$

$$\frac{dh}{dt} = \begin{cases} \frac{1-h}{\tau_{open}} & \text{if } u < u_{gate} \\ \frac{-h}{\tau_{close}} & \text{if } u > u_{gate} \end{cases}$$

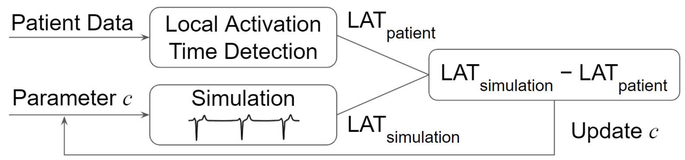
Affects the shape of action potential

Affects the activation propagation speed



An iterative process is performed to minimize local activation time errors across the entire left atrium resulting the optimal heart model parameters.

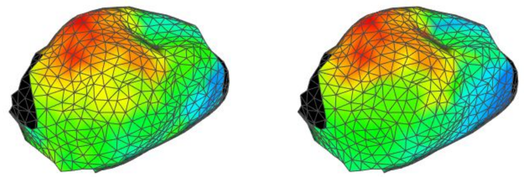
Patient-specific Parameter Optimization



$$c^* = \underset{c}{argmin}\ mean\left(|LAT_{simulation}(c) - LAT_{patient}|\right)$$

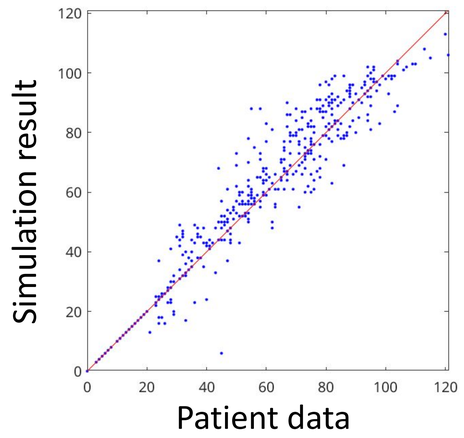
$$d_{new} = d_{old} + \left(LAT_{simulation} - LAT_{patient}\right)\varepsilon$$

Local activation time (LAT) map



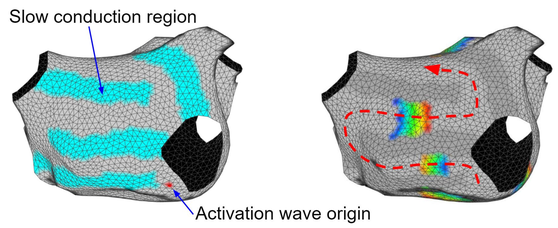
Patient data

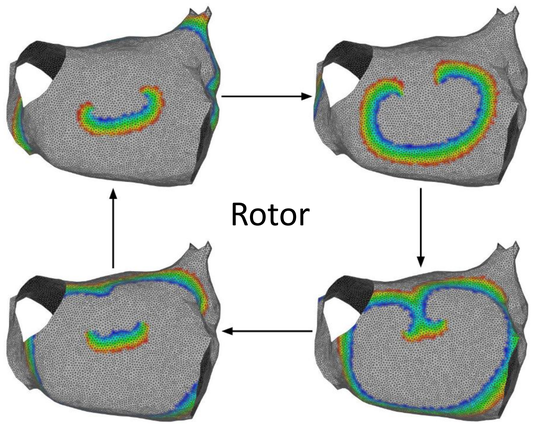
Simulation result



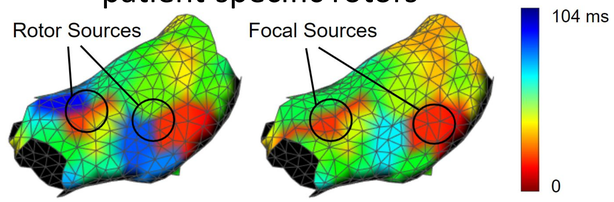
The heart model can accurately reproduce patient atrium activations. It can also simulate atrial fibrillation behaviors such as zigzag propagation and rotors.

Zigzag propagation





Limitation on reproducing patient-specific rotors



Patient data

Simulation result

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