Parametric Modeling of Human Wrist for Bioimpedance-based Physiological Sensing

Kaan Sel[1], Noah Huerta[2], Michael S. Sacks[5], and Roozbeh Jafari[1,3,4]

[1]Departments of Electrical and Computer Engineering, [2]Mechanical Engineering, [3]Biomedical Engineering, [4]Computer Science and Engineering, Texas A&M University, College Station, TX, USA
[5]James T. Willerson Center for Cardiovascular Modeling and Simulation, The Oden Institute and the Department of Biomedical Engineering, University of Texas at Austin, Austin, TX, USA
ksel@tamu.edu, noahmhuerta@tamu.edu, msacks@oden.utexas.edu, rjafari@tamu.edu

Motivation

Objectives: Continuous health monitoring through high-fidelity and robust integration of wearable non-invasive modalities

Significance: Improved diagnostic and prognostic care:

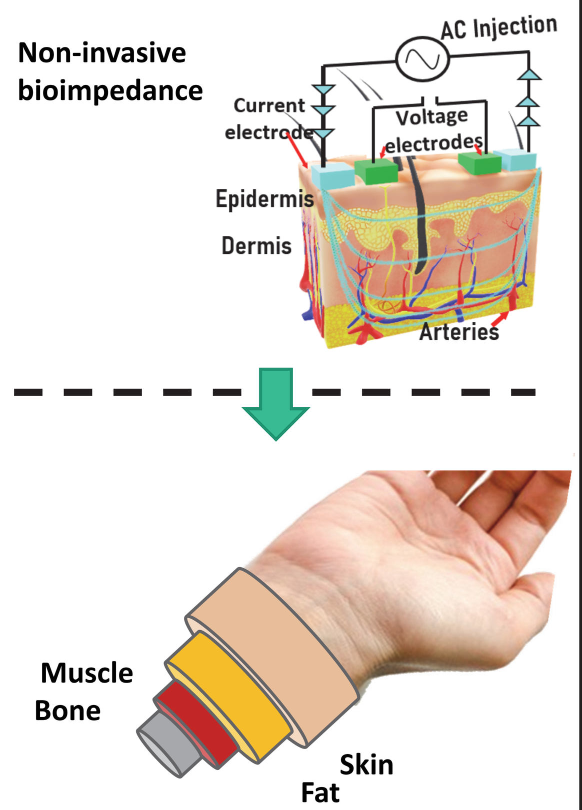
- Early detection of CVD and respiratory symptoms
- Data analytics and wearable health monitoring

Needs and Innovation

Needs: enable high-fidelity bioimpedance sensing through assessment of human body response to the electrical stimulation

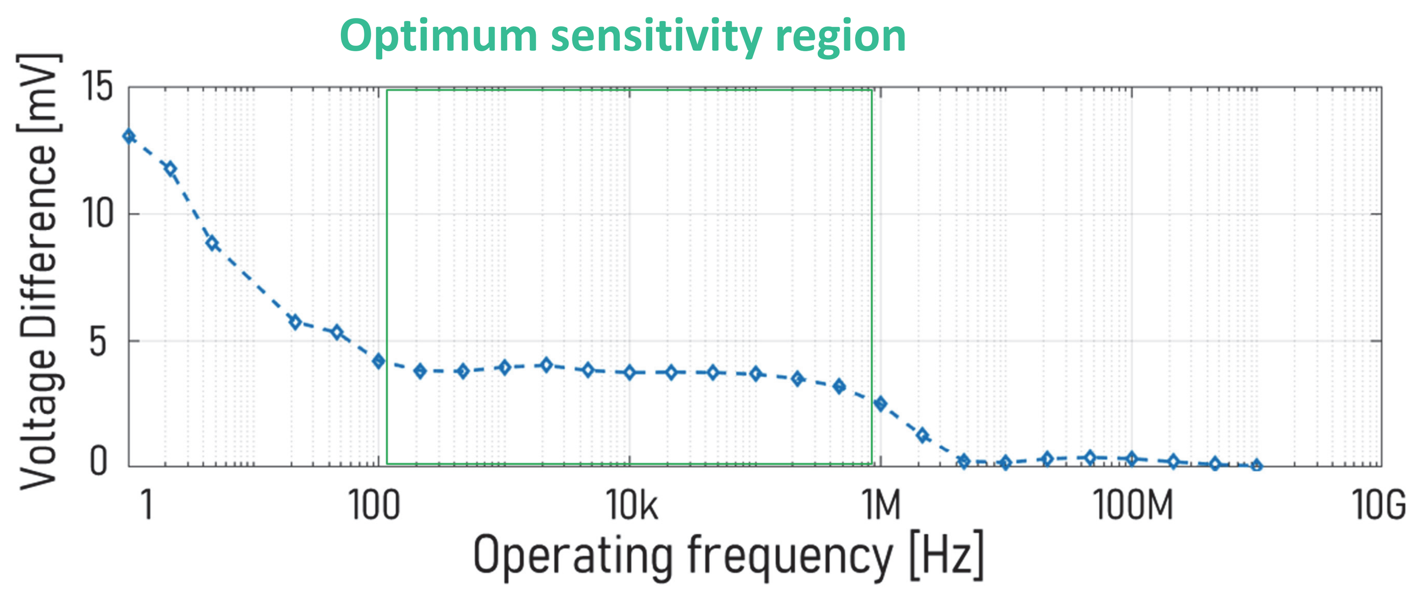
Innovation: 3D Finite Element Model (FEM) of human wrist in COMSOL Multiphysics

- ✓ Provide electrical current mapping within wrist,
- ✓ Localize the blood flow in bioimpedance sensing,
- ✓ Improve specificity and sensitivity in cardiac event monitoring.

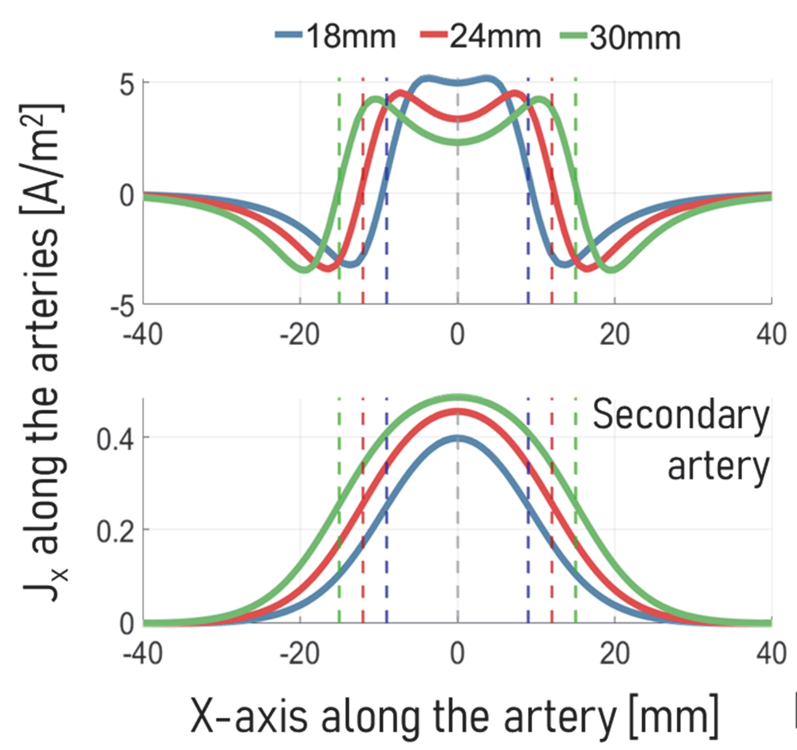


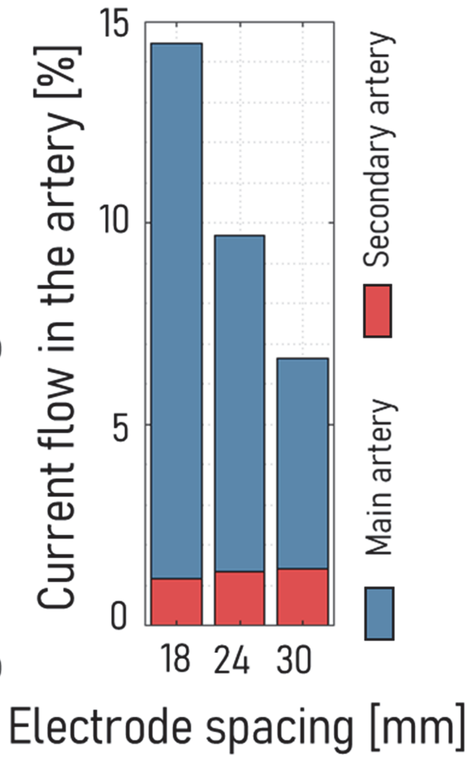
Experimental Results

Pulse Analysis

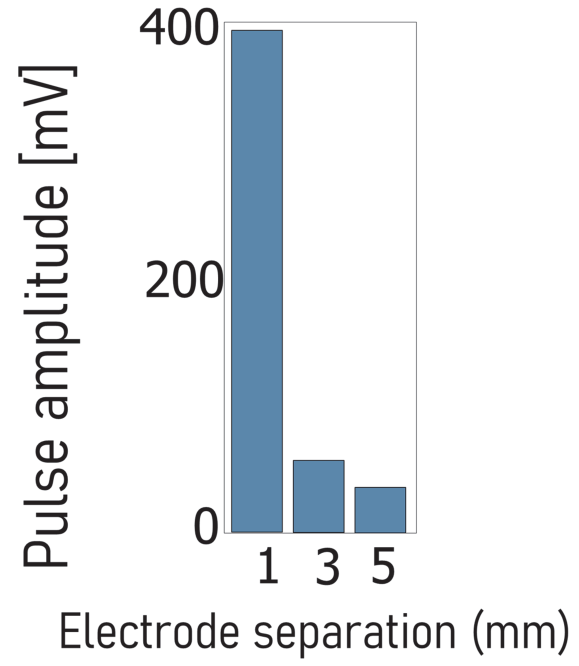


- **Increasing the frequency to 1MHz is adventurous due to the allowance of a higher injection current**



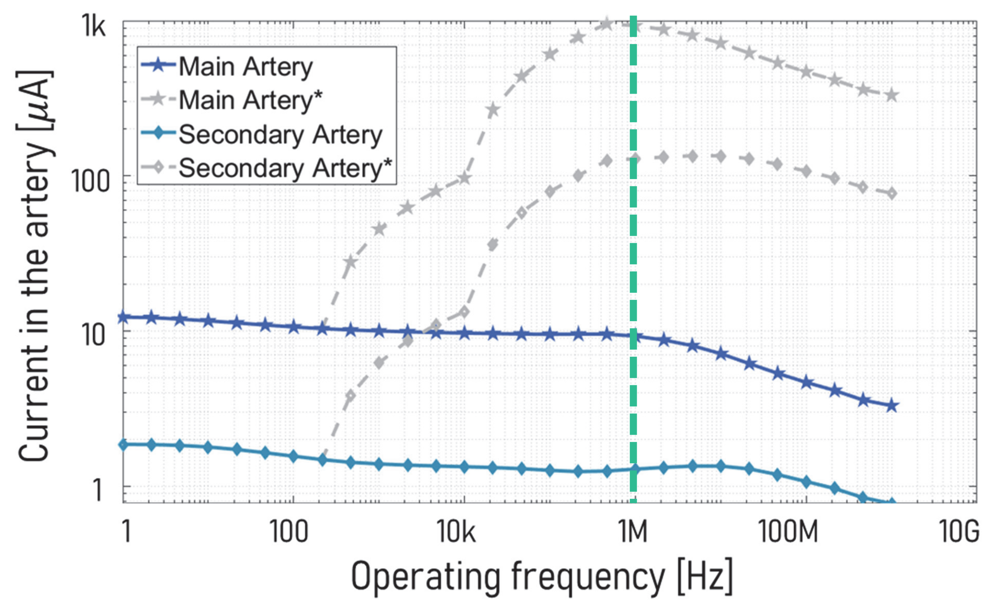


Electrode Spacing

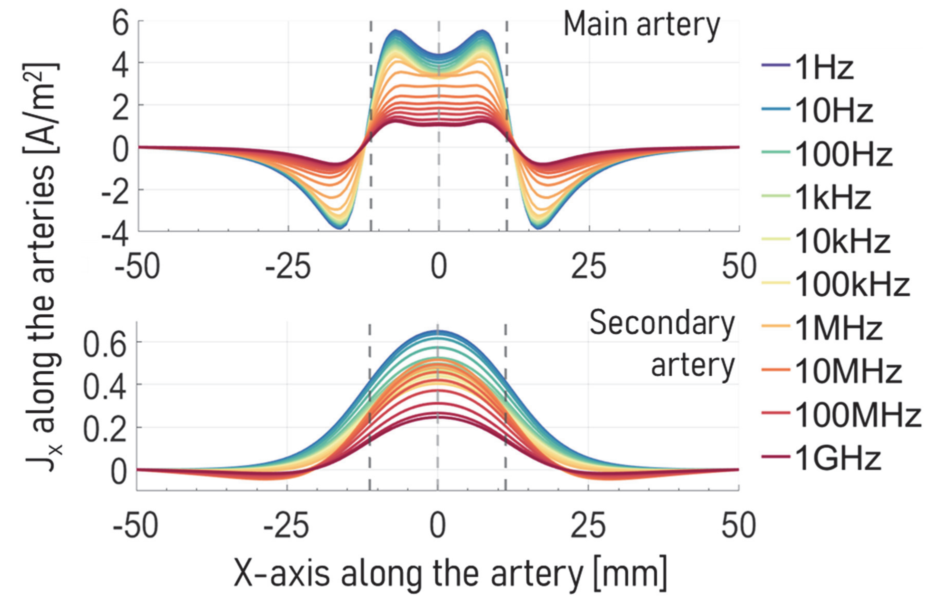


- **Decreasing the spacing is increasing sensitivity (higher current in the 1st artery + higher pulse amplitude).**
- **Decreasing the spacing is increasing specificity (less current flow in the 2nd artery).**

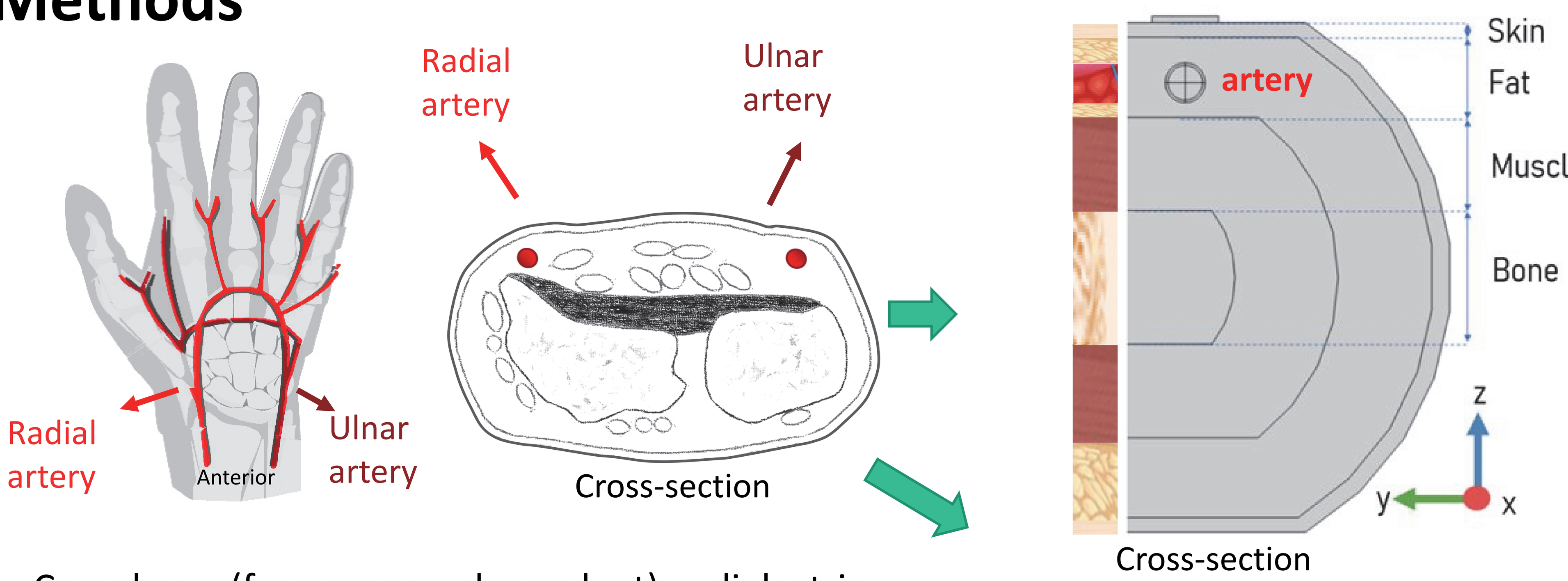
Injection Frequency



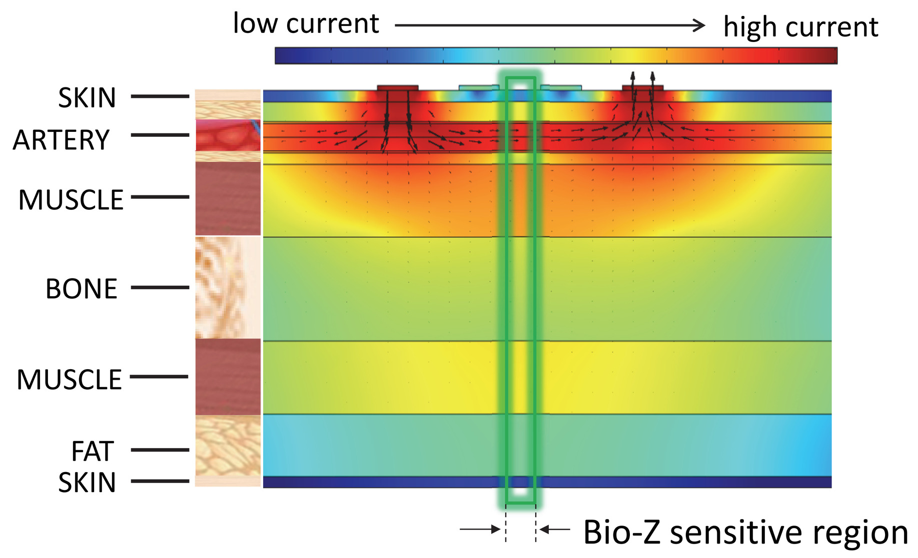
- **Increasing the frequency to 1MHz is adventurous.**
- **Frequency does not play a major role in the specificity.**

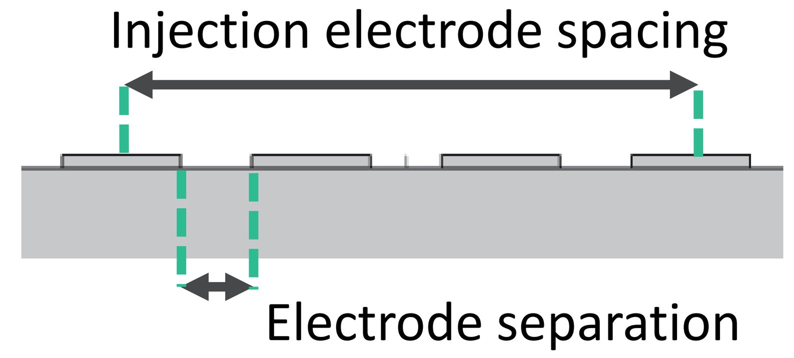


Methods



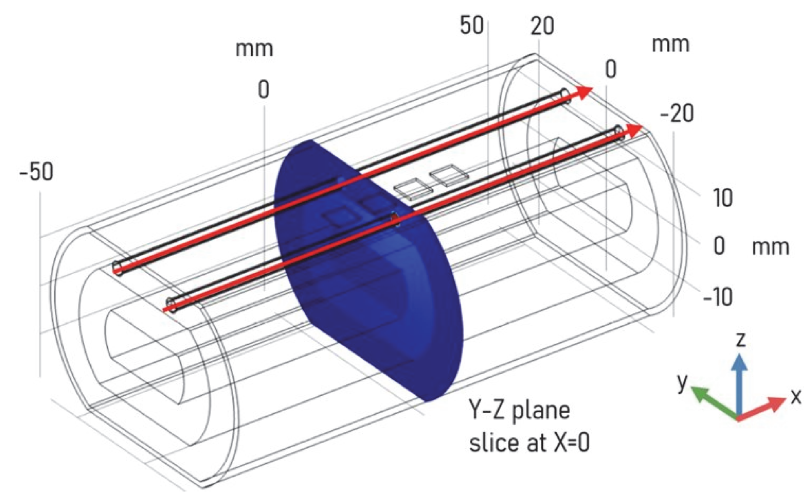
- Complex (frequency dependent) dielectric characteristics,
- Different tissue layers: artery, fat, muscle, bones, skin,
- Bioimpedance sensing relationship with tissue level events (e.g., arterial expansion due to BP pulse wave).
- Cole-Cole dispersion model to simulate permittivity and conductivity under various frequencies from 10 Hz to 1 GHz

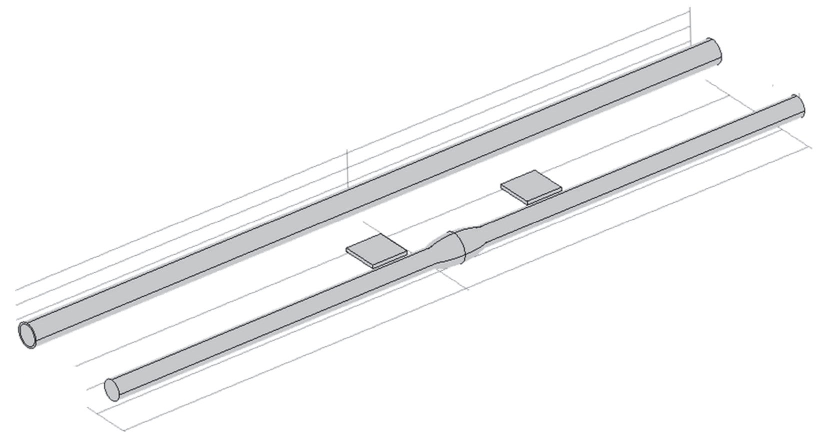




- The injection electrodes were varied at distances of 18mm, 24mm, and 30 mm

- Current density analysis in Y-Z Plane
- Cut line placed in the center of the artery to gather sensitivity information from arteries





- An ellipsoid was created on the artery to simulate pulsatile flow

Summary

The proposed parametric FE model allows for fast and effective testing of different frequency and electrode configurations. From the simulations, it was found that a frequency range of 10 kHz to 100 kHz was optimal. It was also seen that smaller electrode sizes and electrode separations yield higher sensitivity and specificity, with a drawback of higher contact impedance. Our proposed model can provide further investigations related to bioimpedance sensing that are essential for the modality to be used in practical settings

Acknowledgments

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