Professor Luis Gomez
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Title: Computational methods for analysis of brain stimulation and signals.

Abstract: This course will provide a unified description of the physics of brain stimulation technologies and the measurement of brain electromagnetic signals, as well as their analysis using computational methods.

The first two hours will cover computational E-field dosimetry for these modalities. First, we provide a brief introduction to the various brain stimulation modalities (i.e., Transcranial magnetic stimulation (TMS), Transcranial electric stimulation (TES), and Deep brain stimulation (DBS)), and imaging modalities (i.e., Electroencephalogram (EEG) and Magnetoencephalogram (MEG)). Second, starting from a full-wave representation of the E-fields, relevant quasi-static approximations along with conditions for their validity are derived. Third, these quasi-static approximations are then used to derive the relevant differential and integral equations that need to be solved for E-field dosimetry. Fourth, we describe methods for discretization of the differential and integral operators. Finally, we provide numerical results that shed light on required mesh densities for a given numerical error, expected error due to human brain model error, and sensitivity of E-field to various parameters.

The last two hours develop methods for multi-scale biophysical modeling of the E-fields affecting individual and networks of cells' function. First, I introduce the simple cable formalism introduced by Hodkin-Huxley to model the exchange of ions between the inside and outside of the cell. Second, this formalism is used to derive a cable equation that models neuron cells. Third, the commonly used activation function method for modeling neurons is introduced. This method uses E-field dosimetry results as input forcing functions to a cable equation cell solver. The activation function approach is simple. However, it only considers unilateral coupling, which limits its predictive power. Fourth, I develop full bilateral coupled bidomain approaches that simultaneously predict the induced E-field along with cell activity. Finally, several examples that elucidate the strengths and weakness of both activation function and bidomain approaches are given.

Biography: Luis Gomez is an Assistant Professor at Purdue University, West Lafayette,IN,USA, where he is currently developing computational electromagnetics methods for improving brain stimulation technologies. He received his M.S. and Ph.D. degrees in electrical engineering from the University of Michigan, Ann Arbor, MI, USA, in 2014 and 2015, respectively. Additionally, he pursued his postdoctoral studies in the department of psychiatry at Duke University, Durham,NC, USA where he developed focal non-invasive transcranial magnetic brain stimulation coils. Dr. Gomez was the recipient of a K99/R00 brain initiative award and Journal of Neural Engineering Outstanding Reviewer Award in 2019 and a ACES Early Career Award in 2023. His PhD studies where funded through a University of Michigan Rackham Merit Fellowship and the NSF Graduate Research Fellowship. He is the author/co-author of 19 journal papers and more than 50 conference papers/abstracts, and a Senior Member of IEEE.