BE-GY 6353 – A Special Topics in Biomedical Engineering: State-Space Estimation with Physiological Applications

Days and Times: Th 11:00AM-1:30PM
Location: 2 Metrotech, Room 804 Loc: Brooklyn Campus

Prerequisites: Probability theory, Signal processing, and MATLAB.

Course description: State-space modeling, state-space estimation, Kalman filtering, theory of point processes, estimation of point processes, maximum likelihood, expectation maximization, point process filtering and smoothing, and sparse signal processing.

Course topics: This advanced-topic course will present signal processing and statistical methods used to study neural systems and analyze pulsatile physiological signals. Core topics include state-space models, theory of point processes, estimation methods, and inverse problems. Emphasis on developing a firm conceptual understanding of advanced signal processing and statistical methods primarily through analysis of experimental data in form of a course project. Applications of these theoretical techniques include dynamic analyses of neural encoding, neural spike train decoding, and pulsatile physiological data analysis.

Learning objectives and expected course outcomes: Students who successfully complete this course are expected to develop the following skills:
(1) State-space Modeling and Estimation,
(2) Sparse Signal Processing,
(3) Point Process Modeling and Estimation of Static Point Processes,
(4) Point Process Filtering and Smoothing.

Tentative Topics (This is subject to change; how we adhere to this depends in part on the pace that we feel is reasonable for the class.)
State-Space Modeling and Estimation: Deterministic and stochastic state-space models; Kalman filtering; non-causal beliefs; Kalman Smoothing.
Sparse Signal Processing: Introduction to sparse signal processing; applications in analyzing hormone data and electrodermal activity.
Point Processes: Theory of point processes; conditional intensity functions; generalized linear models; point process likelihoods; maximum likelihood; model selection; multivariate point processes.
Point Process Filtering and Smoothing: Expectation maximization; point process filtering; point process smoothing; neural decoding; applications in analyzing heartbeat, behavioral data, and brain machine interfaces.

Course Projects: The course includes potentially publishable research projects. The followings are publications based on the previous offerings of this course:
Journal Papers:
(1) A Mixed Filtering Approach for Real-Time Seizure State Tracking Using Multi-Channel Electroencephalography Data (Project from 2020 class)
(2) Closed-Loop Tracking and Regulation of Emotional Valence State from Facial Electromyogram Measurements (Project from 2020 class).

IEEE Conference Papers:
(3) Decoding a Music-Modulated Cognitive Arousal State using Electrodermal Activity and Functional Near-infrared Spectroscopy Measurements (Project from 2021 class)
(4) Emotional valence tracking and classification via state-space analysis of facial electromyography (Project from 2019 class)
(5) Real-time seizure state tracking using two channels: A mixed-filter approach (Project from 2019 class)
(6) Emotion recognition by point process characterization of heartbeat dynamics (Project from 2018 class)

Disclaimer: Information contained in this document is subject to change without notice. Students are expected to read the course syllabus handed out on the first day of classes and to be aware of any additional course policies presented by the instructor during the course.