Modeling Dynamical Systems – One Day Workshop

Schedule

Time: March 13, 2010; **Location:** ARC Ballroom B

8:00-8:50: breakfast; **8:50-9:00:** welcome remark

9:00-9:50: Jonathan Victor
9:50-10:15: Anne Smith
10:15-10:40: Owen Carmichael

10:40-11:00: coffee break

11:00-11:50: Rongling Wu
11:50-12:15: Wendy Silk
12:15-12:30: Fushing Hsieh

12:30-2:00: lunch break (in cafeteria)

2:00-2:50: Hulin Wu
2:50-3:05: Hans Müller
3:05-3:20: Jie Peng

3:20-3:40: coffee break

3:40-4:30: Alan Hastings
4:30-4:55: James Crutchfield

4:55-5:15: coffee break

5:15-5:40: Emilio Ferrer
5:40-5:55: Debashis Paul

5:55-6:00: concluding remark; **6:00-7:00:** reception (in MSB, 4th floor)

Abstracts of Talks

Keynote Speeches

Spatiotemporal dynamics in ecological systems

Speaker: Alan Hastings

Affiliation: Department of Environmental Science and Policy, University of California, Davis

Abstract

I will discuss some of the complexities involved in spatiotemporal dynamics in ecological systems, focusing on two aspects: the role of stochasticity in spatial spread and the dynamics of regime shifts. In discussing the role of stochasticity in spatial spread I will be emphasizing variance as uncovered in a laboratory system with flour beetles. This will naturally lead to discussions of regime shifts (sudden changes in dynamical behavior as in eutrophication) and the possibilities for detecting warning signs.

Towards an understanding of chronic brain injury as a dynamical disease: a population-based model of thalamocortical circuits and EEG observables

Speaker: Jonathan Victor

Affiliation: Department of Neurology and Neuroscience, Cornell University

Abstract

Higher brain function depends on dynamic interactions of multiple cortical and thalamic populations. In patients with chronic disturbances of these functions due to brain injury, converging lines of evidence suggest that dynamical disturbances of these interactions play a crucial role in pathogenesis. However, assaying these interactions is challenging in healthy subjects, and even more so in severely impaired patients. With the goal of understanding how these interactions are manifest in the EEG, we have begun to build a model of thalamocortical populations. The basic building block is the thalamocortical module (cortex, relay nucleus, and reticular nucleus). We show that when two such modules are coupled via a shared reticular nucleus, multistable behavior emerges, with each mode characterized by a different pattern of corticocortical coherence. These observations support the role of the reticular thalamus in the organization of patterns of cortical interactions, and we present preliminary data that show how these features can be identified in the EEG. Authors: Jonathan D. Victor, Nicholas D. Schiff, Jonathan D. Drover

A review and recent development on statistical estimation for dynamic systems

Speaker: Hulin Wu

Affiliation: Department of Biostatistics and Computational Biology, Division of Biomedical Modeling and Informatics, Center for Biodefense Immune Modeling, University of Rochester School of Medicine and Dentistry

Abstract

Differential equation models are widely used to describe engineering, physical and biological processes. However, parameter estimation methods and statistical inference approaches are quite challenging and not well developed for differential equation models. This definitely limits the applications of the dynamic models in the real world. We believe that it is critical and important to accurately and robustly identify the dynamic models and parameters based on experimental data. In this talk, I will present several novel statistical approaches to estimate constant and time-varying parameters in ordinary differential equation models. Generalizations of these methods for dealing with high-dimensional different equation models and high-dimensional parameter space will be discussed. The applications of these methods to modeling viral dynamics will be used to illustrate the usefulness of these methods.

Modeling genetic interactions of complex traits using design principles of biological systems

Speaker: Rongling Wu

Affiliation: Center for Statistical Genetics, Pennsylvania State University

Abstract

The formation of any phenotypic trait undergoes complex interactions and coordination of its different components expressed at various organizational levels from cell to tissue to organ to organism. These interactive relationships among components can be understood by developing a system of differential equations that describe the dynamic behavior and coordination of the biological system based on natural laws. In this talk, I will present a conceptual model for integrating a system of differential equations into a framework for genetic mapping, allowing the characterization of genes and genetic interactions involved in the regulation of biological circuits. The model provides a quantitative and testable platform for assessing the interplay between gene action and development. The new model should help shed light on the genetic control mechanisms of biological systems and predict physiological and pathological states of the systems.

Invited Talks

Dynamics of brain changes and cognitive changes in aging and late-life neurodegenerative disease

Speaker: Owen Carmichael

Affiliation: Departments Neurology and Computer Science, University of California, Davis

Abstract

Performance of higher-order cognitive tasks such as memory, learning, language, and attention depends critically on the coordinated functioning of distributed networks of neuronal structures in the brain. As the brain ages, a wide variety of neuropathological processes cause progressive damage to these brain structures and the connections between them, causing progressive decline in cognitive abilities. Because a multifactorial array of factors can influence the trajectories of late-life brain changes for better or worse, heterogeneity in late-life cognitive trajectories across the general population is substantial. Characterizing the relative dynamics of brain changes and cognitive changes requires sophisticated modeling of longitudinal data from neuroimaging and cognitive testing, and their relationships to predictors such as genetics, background factors, and cardiovascular health. This talk will give an overview of efforts here at UC Davis to characterize dynamic brain and cognitive changes based on imaging and cognitive data from the UCD Alzheimer's Disease Center.

The past and the future in the present

Speaker: James Crutchfield

Affiliation: Complexity Sciences Center and Department of Physics, University of California, Davis

Abstract

We show why the amount of information communicated between the past and future—the excess entropy—is not in general the amount of information stored in the present—the statistical complexity. This is a puzzle, and a long-standing one, since the former describes observed behavior, while optimal prediction requires the latter. We present a closed-form expression for the excess entropy in terms of optimal causal predictors and retrodictors—both epsilon-machines of computational mechanics. This leads us to two new system invariants: causal irreversibility—the asymmetry between the causal representations—and crypticity—the degree to which a process hides its state information.

Analyzing dynamics of affective dyadic interactions using patterns of intra- and inter-individual variability

Speaker: Emilio Ferrer

Affiliation: Department of Psychology, University of California, Davis

Abstract

We present an algorithm for examining the dynamics of affect between individuals in couples based on patterns of variability. The algorithm identifies periods of stability based on length of time and amplitude of emotional fluctuations. The patterns of variability and stability are quantified at the individual and dyadic level. We examine the fluctuations of the emotions for each person and inspect the overlap fluctuations between both individuals in the dyad. The individual and dyadic indices of variability are then used to predict the status of the dyads (i.e., together, break-up) one year later.

Discovering focal regions of slightly-aggregated sparse signals

Speaker: Fushing Hsieh

Affiliation: Department of Statistics, University of California, Davis

Abstract

We characterize the dynamic distortions on a time series of i.i.d. pure noise when it is embedded with slightly-aggregating sparse signals. The distortion patterns are perceived through a chosen events recurrence time process and its marginal distribution, and are shown to depend on varying degrees of aggregation of sparse signals from a completely random distribution of singletons to batches of various sizes on the entire temporal span. We demonstrate that the Kolmgorov-Smirnov statistic captures the marginal distributional distortions better than does Tukeys Higher Criticism statistic when the batch size is as small as five. Then we apply the Hierarchical Factor Segmentation (HFS) algorithm based on the recurrence time process to compute focal segments which contain a significantly higher intensity of signals than do the rest of the temporal regions. In a computer experiment with a given fixed number of signals, the focal segments identified by the HFS algorithm afford many folds of signal intensity which critically depend on the degree of aggregation of sparse signals. This ratio information can facilitate better sensitivity, equivalent to a smaller false discovery rate, if the signal-discovering protocol implemented within the computed focal regions is different from that used outside of the focal regions. We also numerically compute the specificity as the total number of signals contained in the computed collection of focal regions. This number is a measure of the inherent difficulty in a task such as sparse signal discovery.

Empirical dynamics

Speaker: Hans Müller

Affiliation: Department of Statistics, University of California, Davis

Abstract

Empirical dynamics aims at determining features of an underlying dynamic system from an observed sample of longitudinal data, which are assumed to be generated by a smooth but unobserved Gaussian process. Key steps are obtaining derivatives for sparsely and irregularly sampled trajectories, as typically encountered in longitudinal studies, which requires borrowing information across subjects; fitting an automatically implied population-level linear differential equation with time-varying coefficient functions; and assessing the properties of a drift process in a simple stochastic differential equation that applies for subject-specific trajectories. Based on joint work with Bitao Liu, Wenjing Yang and Fang Yao.

Estimation of state space models under natural identifiability constraints

Speaker: Debashis Paul

Affiliation: Department of Statistics, University of California, Davis

Abstract

State space models are widely used in modeling multivariate time series. A linear state space model is defined through a pair of linear equations called the *observation equation*, connecting the underlying state variable to the observed time series, and the *state equation*, describing the dynamics of the underlying state variable. In many problems involving a state space formulation, at least one of these linear equations is completely specified, usually from the physical description of the problem. However, in problems where there is insufficient information to be able to completely specify any of these equations, the state space model is not identifiable. This nonidentifiability has implications both in terms of obtaining meaningful estimates of the parameters as well as in terms of convergence of the estimation procedures. We impose a geometric identifiability constraint on the parameters and propose an algorithm that combines the traditional *Kalman filtering* method with optimization over a *Stiefel manifold*. Based on joint work with Wei-Shan Hsieh and Jie Peng.

Semiparametric modeling of autonomous nonlinear dynamical systems

Speaker: Jie Peng

Affiliation: Department of Statistics, University of California, Davis

Abstract

In this talk, we discuss a semi-parametric model for autonomous nonlinear dynamical systems and devise an estimation procedure for model fitting. This model incorporates subject-specific effects and can be viewed as a nonlinear semi-parametric mixed effects model. We also propose a computationally efficient model selection procedure. Based on joint work with Debashis Paul and Prabir Burman.

Modeling the hydraulics of root growth in three dimensions with phloem water sources

Speaker: Wendy Silk

Affiliation: Department of Land, Air and Water Resources, University of California, Davis

Abstract

Primary growth is characterized by cell expansion facilitated by water uptake generating hydrostatic (turgor) pressure to inflate the cell, stretching the rigid cell walls. The multiple source theory of root growth hypothesizes that root growth involves transport of water both from the soil surrounding the growth zone and from the mature tissue higher in the root via phloem and protophloem. Here, protophloem water sources are used as boundary conditions in a three-dimensional model of growth-sustaining water potentials in primary roots. The model is based on the Reynolds Transport Theorem for water transport into the expanding, moving cell in response to a water potential differential. The model predicts small radial gradients in water potential, with a significant longitudinal gradient. The results improve the agreement of theory with empirical studies for water potential in the primary growth zone of roots of maize (Zea mays). A sensitivity analysis quantifies the functional importance of apical phloem differentiation in permitting growth and reveals that the presence of phloem water sources makes the growth-sustaining water relations of the root relatively insensitive to changes in root radius and hydraulic conductivity. Adaptation to drought and other environmental stresses is predicted to involve more apical differentiation of phloem and/or higher phloem delivery rates to the growth zone. Authors: Brandy S. Wiegers, Angela Y. Cheer, and Wendy K. Silk

Dynamic analysis of learning using state-space models

Speaker: Anne Smith

Affiliation: Department of Anesthesiology and Pain Medicine, University of California, Davis

Abstract

For data arising from neuroscience experiments, the statistical modeling framework suggests several advantages. For example, statistical models can locate change points in data, obviate multiple-comparison problems, and the optimal model can be picked using model selection criteria. In this talk, I will describe application of Bayesian statistical models to learning during behavioral experiments in monkeys.