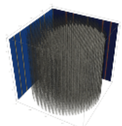
March 2022 APS Meeting Group on Data Science

Longitudinal Data Tensor-Linear Modeling and Space-kime Analytics
Short Course (March 13,2022)
https://march.aps.org/events/gds-short-course
https://myumi.ch/G1411

Instructors

Maryam **Bagherian** | Miaoyan **Wang** | Raj **Guhaniyogi** | Anru **Zhang** | Ivo **Dinov**



Program

Morning Session (9:00-12:00 US Central Time, GMT-5)			Afternoon Session (13:00-17:00 US Central Time, GMT-5)		
Time	**Presenter**	**Topic**	**Time**	**Presenter**	**Topic**
9:00-9:15	Ivo Dinov	Welcome & Overview	13:00-13:45	Presenter 3 Raj Guhaniyogi (Talk)	Bayesian Tensor Regression
9:15-10:00	Presenter 1 Maryam Bagherian (Talk)	Distance Metric Learning	13:45-14:15	Presenter 3 Raj Guhaniyogi (Demo)	
10:00-10:30	Presenter 1: Maryam Bagherian (Demo)		14:15-15:00	Presenter 4 Anru Zhang (Talk)	Tensor Learning
10:30-10:45	Break		15:00-15:10	Break	
10:45-11:30	Presenter 2 Miaoyan Wang (Talk)	Higher-order Tensor Methods	15:10-15:40	Presenter 4 Anru Zhang (Demo)	Tensor Learning
11:30-12:00	Presenter 2 Miaoyan Wang (Demo)		15:40-16:25	Presenter 5 Ivo Dinov (Talk)	Longitudinal Spacekime Analytics
12:00-13:00	Break (lunch recess)		16:25-16:55	Presenter 5 Ivo Dinov (Demo)	

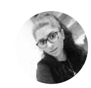
Topic 1

Speaker: Maryam Bagherian, Michigan

Title: *Tensor Methods under Distance Metric Learning Constraints: Completion, Decomposition, Recovery and Reconstruction*

Outline: Rapid growth in quantity and variety of data presents enormous opportunities in AI data-driven inference and decision-support. In practice, data complexity often exceeds the capacity of current matrix based data representations which limits the applications of many current analysis algorithms. Tensors represent a powerful framework for modeling, analysis and visualization of high-dimensional data and are capable of storing and tracking structural information in heterogeneous datasets. Tensor recovery and reconstruction have emerged as the key tools to investigate high-dimensional multi-modal noisy and partially observed datasets. To capture such complex data structures, we introduce a new approach to tensor methods using distance metric learning (DML). Metric learning constraints, implemented as bilevel optimization methods, ensure that this technique accurately estimates the tensor model factors, even in the presence of missing entries and noise.

Topic 1



Speaker: Maryam Bagherian, Michigan

Title: *Tensor Methods under Distance Metric Learning Constraints: Completion, Decomposition, Recovery and Reconstruction*

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Topic 2

Presenter: Miaoyan Wang, Wisconsin

Title: *Beyond matrices: higher-order tensor methods meet computational biology*

Outline: Higher-order tensors arise frequently in applications such as neuroimaging, recommendation system, social network analysis, and psychological studies. Rapid developments in high-throughput technologies have made multiway data readily available in daily lives. Tensor provides a generalized data structure in many learning procedures. Methods built on tensors provide powerful tools to capture complex structures that lower-order methods fail to exploit. However, the empirical success has uncovered a myriad of new and pressing challenges. In this talk, I will discuss some recent advances and challenges in high-dimensional tensor data algorithms. Potentials of these methods are illustrated through applications to Human Connectome Project (HCP) and Genotype-Tissue Expression (GTEx) datasets.

Topic 2

Presenter: Miaoyan Wang, Wisconsin

Title: Beyond matrices: higher-order tensor methods meet computational biology

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Topic 3

Presenter: Raj Guhaniyogi, TAMU

Title: *Bayesian High-dimensional Regressions with Tensors and Distributed Computation with Space-time Data*

Outline: Of late, neuroscience, environmental science or related applications routinely encounter regression scenarios involving multidimensional array or tensor structured responses or predictors. In the first half of this course, we will discuss how to perform Bayesian regression with tensor response and/or predictors, the construction of prior distributions on tensor-valued parameters and posterior inference. We will present applications of the proposed methodology in brain activation and connectivity studies. The second half of this course will be devoted to the study of recently emerging literature on divide-and-conquer Bayesian inference in massive spatio-temporal data. We will discuss how to draw distributed Bayesian inference in space-time data with parallel computing architecture, theoretical studies in distributed approaches and applications in large scale environmental datasets.

Topic 3

Presenter: Raj Guhaniyogi, TAMU

Title: *Bayesian High-dimensional Regressions with Tensors and Distributed Computation with Space-time Data*

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Topic 4

Presenter: Anru Zhang, Duke

Title: *High-dimensional Tensor Learning: Methodology, Theory, and Applications*

Outline: The analysis of tensor data, i.e., arrays with multiple directions, has become an active research topic in the era of big data. Datasets in the form of tensors arise from a wide range of applications, such as neuroimaging, genomics, and computational imaging. Tensor methods also provide unique perspectives to many high-dimensional problems, where the observations are not necessarily tensors. Problems with high-dimensional tensors generally possess distinct characteristics that pose unprecedented challenges; there are strong demands to develop new methods for them.

We specifically focus on how to perform singular value decomposition (SVD), a fundamental task of unsupervised learning, on general tensors or tensors with structural assumptions, e.g., sparsity, smoothness, and longitudinality. Through the developed frameworks, we can achieve accurate denoising for 4D scanning transmission electron microscopy images; in longitudinal microbiome studies, we can extract key components in the trajectories of bacterial abundance, identify representative bacterial taxa for these key trajectories, and group subjects based on the change of bacteria abundance over time. We also illustrate how we develop new methods that exploit useful information from high-dimensional tensor data based on the modern theories of computation and non-convex optimization.

Topic 4

Presenter: Anru Zhang, Duke

Title: *High-dimensional Tensor Learning: Methodology, Theory, and Applications*

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Topic 5

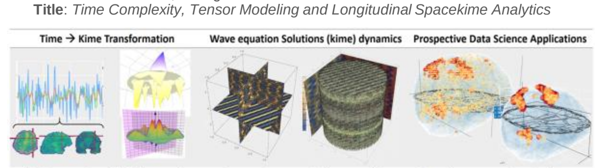
Presenter: Ivo Dinov, Michigan

Title: *Time Complexity, Tensor Modeling and Longitudinal Spacekime Analytics*

Outline: Many observable processes demand managing, harmonizing, modeling, analyzing, interpreting, and visualizing of large and complex information. Spacekime analytics uses complex time for modeling high-dimensional longitudinal data. This approach relies on extending the notions of time, events, particles, and wavefunctions to complex-time (kime), complex-events (kevents), data, and inference-functions. We will illustrate how the kime-magnitude (longitudinal time order) and kime-direction (phase) affect the subsequent predictive analytics and the induced scientific inference. The mathematical foundation of spacekime calculus reveal various statistical implications including inferential uncertainty, tensor linear modeling, and a Bayesian formulation of spacekime analytics. Complexifying time allows the lifting of all commonly observed processes from the classical 4D Minkowski spacetime to a 5D spacekime manifold, where a number of interesting mathematical problems arise. Direct data science applications of spacekime analytics will be demonstrated using simulated data and clinical observations (e.g., structural and functional MRI). Joint work with Milen V. Velev (Burgas University).

Topic 5

Presenter: Ivo Dinov, Michigan
Title: *Time Complexity, Tensor Modeling and Longitudinal Spacekime Analytics*



Spacekime: **https://spacekime.org** **Demos:** **https://tciu.predictive.space**

References: **https://www.socr.umich.edu/people/dinov/publications.html**

Thank you for your participation

Course Website URL: **https://myumi.ch/G1411**

Additional resources: will be posted on the course website

Course evaluation: Please consider completing a short (anonymous) course post-evaluation survey (available in the website)

Contact information: Participants can contact any of the instructors, see website, or send an email to statistics@umich.edu