THE GEORGE WASHINGTON UNIVERSITY STUDENT CHAPTER OF SIAM

Spring 2024 Conference on Applied Mathematics

Washington DC

April 13, 2024

Timetable

9:00 - 9:45
Registration and Breakfast

9:45 - 10:00
Open Remark: Frank E. Baginski, The George Washington University

10:00 - 10:30
Dong An, University of Maryland, College Park

10:30 - 11:00
Jessica Masterson, George Mason University

11:00 - 11:20
Break

11:20 - 11:50
Rohit Khandelwal, George Mason University

11:50 - 12:20
Derek (Binshuai) Wang, The George Washington University

12:20 - 12:30
Picture Time

12:30 - 2:00
Lunch

2:00 - 2:30
Zezheng Song, University of Maryland, College Park

2:30 - 3:00
Yaqi Wu, The George Washington University

3:00 - 3:30
Jingjing Xu, Amazon

Dong An
University of Maryland, College Park

Title

Quantum algorithms for linear differential equations

Abstract

Quantum computers are expected to simulate unitary dynamics (i.e., Hamiltonian simulation) much faster than classical computers. However, most applications in scientific computing involve non-unitary dynamics and processes. In this talk, we will discuss a recently proposed quantum algorithm for solving general linear differential equations. The idea of the algorithm is to reduce general differential equations to a linear combination of Hamiltonian simulation (LCHS) problems. For the first time, this approach allows quantum algorithms to solve linear differential equations with near-optimal dependence on all parameters. Additionally, we will discuss a hybrid quantum-classical differential equation algorithm based on LCHS, which may be more feasible on near-term quantum devices.

(This talk assumes no prior knowledge in quantum computation and information, and is based on [arXiv:2303.01029, arXiv:2312.03916].)

Rohit Khandelwal
George Mason University

Title

The Obstacle Problem: Optimal Control and Elliptic Reconstruction

Abstract

Free boundary problems governed by physical principles are ubiq- uitous in science and engineering. In particular variational inequalities of first kind, such as obstacle problem, arise in elasticity, fluid filtration in porous me- dia and finance. Special attention has been given to study the obstacle problem which acts as a model problem in many of these applications. In this talk, we focus on the obstacle problem. In the first part, we focus on the a priori error estimates for an optimal control problem constrained by an elliptic obstacle problem where the finite element discretization is carried out using the symmetric interior penalty discontinuous Galerkin method. The main proofs are based on the improved L^2-error estimates for the obstacle problem, the discrete maximum principle, and a well-known quadratic growth property. This is a joint work with Prof Harbir Antil and Umarkhon Rakhimov (GMU). For the second part of the talk, we discuss the elliptic reconstruction property (originally introduced by Makridakis and Nochetto for linear parabolic prob- lems), is a well-known tool to derive optimal a posteriori error estimates. No such results are known for nonlinear and nonsmooth problems such as parabolic variational inequalities (VIs). We establish the elliptic reconstruction property for parabolic VIs and derive a posteriori error estimates in $L^\infty(0,T;L^2(\Omega))$ and $L^\infty(0,T;L^\infty(\Omega))$, respectively. As an application, the residual-type error estimates are presented. This is a joint work with Prof Harbir Antil.

Jingjing Xu
Amazon

Title

An Introduction to Advertising Technology

Abstract

In a world where consumer attention is a highly desired resource, the landscape of advertising has undergone a major shift from traditional methods to a complex, dynamic digital ecosystem. This talk aims to do a brief introduction to modern advertising technology through its evolution, current practices, and the implications of its future trajectory. We begin our journey with a historical overview of advertising, tracing its roots from print media to the rise of the internet and digital platforms. The focus will then shift to targeting, which enables advertisers to reach their desired audience. We will discuss the transformation of raw data into actionable insights for effective audience segmentation, alongside the privacy concerns that have emerged in the age of big data. Furthermore, we investigate the planning process behind successful ad campaigns, outlining the integration of market research, media planning, and creative development. Additionally, we will cover essential metrics that assess campaign performance, from the standard click-through rates to sentiment analyses. By understanding these analytics, marketers can refine their approaches and drive higher returns on investment. Finally, the presentation will look into potential future advances in ad tech, such as artificial intelligence and immersive experiences, and consider their possible impacts on the advertising industry.

Jessica Masterson
George Mason University

Title

Modeling and optimization applied to cryopreservation

Abstract

In cryobiology, tissue is frozen in a liquid for the purposes of preservation. To mitigate the tissue damage due to ice formation, the liquid contains a cryoprotective agent, or CPA, that also permeates into the tissue. However, prolonged exposure to the CPA can also cause damage. This is the basis of an optimal control problem, where we wish to minimize the damage to the tissue. To calculate the tissue damage, we created a coupled partial differential equation model of the temperature, concentrations, and moving interface dynamics. We solved this model using numerical methods to help identify optimal cryopreservation protocols. To improve the computational efficiency, we are also exploring adjoint approaches to calculate the gradient of the objective function.

Zezheng Song
University of Maryland, College Park

Title

A Finite Expression Method for Solving High-Dimensional Committor Problems

Abstract

Transition path theory (TPT) is a mathematical framework for quantifying rare transition events between a pair of selected metastable states A and B. Central to TPT is the committor function, which describes the probability to hit the metastable state B prior to A from any given starting point of the phase space. Once the committor is computed, the transition channels and the transition rate can be readily found. The committor is the solution to the backward Kolmogorov equation with appropriate boundary conditions. However, solving it is a challenging task in high dimensions due to the need to mesh a whole region of the ambient space. In this work, we explore the finite expression method (FEX, Liang and Yang (2022)) as a tool for computing the committor. FEX approximates the committor by an algebraic expression involving a fixed finite number of nonlinear functions and binary arithmetic operations. The optimal nonlinear functions, the binary operations, and the numerical coefficients in the expression template are found via reinforcement learning. The FEX-based committor solver is tested on several high-dimensional benchmark problems. It gives comparable or better results than neural network-based solvers. Most importantly, FEX is capable of correctly identifying the algebraic structure of the solution which allows one to reduce the committor problem to a low-dimensional one and find the committor with any desired accuracy.

Derek (Binshuai) Wang
The George Washington University

Title

Identifying Similar Thunderstorm Sequences for Airline Decision Support
Using Optimal Transport Theory

Abstract

We propose a new method for identifying similar spatial-temporal thunderstorm sequences to support airline operations based on the optimal transport (OT) theory. Our strategy conceptualizes each thunderstorm as a probability distribution, based on the observed weather images or radar point clouds. The core of our approach lies in measuring the similarity between thunderstorm sequences through the Wasserstein distance of their respective probability distributions. We will demonstrate the power of the new framework in the following experiments: (1) identifying thunderstorm similarities (for both static images and moving sequences); (2) OT-based interpolation between time steps of a thunderstorm event; and (3) clustering thunderstorm data into different categories for generating different thunderstorm patterns.

Yaqi Wu
The George Washington University

Title

Supervised Gromov-Wasserstein Optimal Transport

Abstract

The Gromov-Wasserstein(GW) distance, formulated as a nonconvex quadratic optimiza- tion problem, is based on the idea of comparing the internal structures of the two metric measure spaces. Recently, various efforts have been made to improve computational efficiency and relax the strict constraints in GW to improve its practical applicability. In this talk, we introduce supervised Gromov-Wasserstein(sGW) optimal transport framework to handle the matching problem between two datasets $X = \{x_i\}_i$ and $Y = \{y_j\}_j$ in distinct underlying metric spaces by avoiding the correspondence between (x_i,x_j) and (y_k,y_l) when the difference between $\|x_i-x_j\|$ and $\|y_k-y_l\|$ exceeds certain threshold. sGW extends the capabilities of GW by offering a flexible method for applications that have geometric restrictions such as single-cell genomics. Furthermore, we develop an sGW solver based on a heuristic minimum vertex cover algorithm, the Mirror-C descent algorithm, and the supervised optimal transport solver. We also prove that the sequence generated by the sGW solver converges to a stationary point of the non-convex sGW objective provided that the step size is sufficiently small in the Mirror-C descent al- gorithm. Finally, by comparing sGW with other GW variants on synthetic data and practical single-cell RNA sequencing data, we highlight its distinctive advantage in overseeing the optimal matching.