Speaker 1: Achyut Panchal (Georgia Tech)

Title: Physics-based and data-driven modeling of multiphase reactive flows in aerospace propulsion applications

Abstract: Large eddy simulation (LES) is a high-fidelity approach for modeling turbulent reactive flows. This approach resolves the larger scales of the fluid dynamics on a computational grid, whereas the sub-scale effects, e.g., reactions, spray, etc. are modeled. LES application to real aerospace propulsion systems faces severe challenges due to the multi-physics and multi-scale nature of the problem, uncertainties of boundary or initial conditions, geometrical complexities, and often an intractable computational cost. The application of LES to multiphase combustion modeling in gas-turbine and rotating detonation engines is discussed first to demonstrate these challenge. The results are benchmarked against available measurements and some avenues for improving cost and accuracy of the existing modeling are noted. Next, a data-driven model is developed from the available simulation data to address the intractable computational cost of conducting any parametric variations and obtained results are discussed.

Speaker 2: Amy Sims (Georgia State University)

Title: On mathematical modeling of cell proliferation in tissue-engineering scaffolds with branching channels

Abstract: Tissue engineers seek to artificially manufacture new human tissue for transplant when it becomes damaged or diseased by seeding cells onto a scaffold and feeding them nutrient-filled fluid to engender proliferation. Experimental progress is costly and time-consuming; therefore, we develop mathematical models to predict the most effective designs of these scaffolds and the optimal values for input parameters such as porosity, shear stress, nutrient concentration, and nutrient flow pressure. Our model utilizes a branching structure wherein pores bifurcate at each layer junction, thereby allowing for investigation of the input parameters at a pore level. We exploit and customize established governing equations such as the Hagen-Poiseuille and advection-diffusion-reaction equations to model fluid flow and nutrient transport under a constant inlet flux of suspended nutrients. By assuming homogeneity along two axes, the biological scaffold's geometry is effectively reduced to one dimension; further simplification is achieved via nondimensionalization and asymptotic analysis based on the small aspect ratio of the scaffold. Our results establish quantitative relationships among the input parameters to provide a foundation for effectual construction of engineered tissue in the shortest time possible. Further, we find comparisons among differing ratios of layer thickness and pore radius between layers that prescribe ideal scaffold geometry according to priorities of time, cost, or total volume. This project builds from our recently published work on tissue engineering in a simplified continuum model by offering more complex geometry toward the goal of more precise results, albeit with greater computational cost.

Speaker 3: Dilmini Warnakulasooriya (Georgia State University)

Title: Mechanism of EADs in Hypertrophic Mouse Ventricular Myocytes

Abstract: Compensated cardiac hypertrophy is considered as an adaptive response of the myocytes to increased workload and develops at early stages of heart failure. Experimentally, cardiac hypertrophy is induced by the procedure called transverse aortic constriction (TAC) during the first week after surgery. It is believed that during the early stage of hypertrophy the heart increases its function without adverse effects. To investigate cardiac hypertrophy, we developed a new comprehensive compartmentalized mathematical model of hypertrophic mouse ventricular myocytes that described the cell geometry, cardiac action potentials, $[Ca^{2+}]_i$ transients, and β1- and β2-adrenergic signaling systems. Simulation results obtained with the hypertrophic cell model were compared to those from the normal ventricular myocyte

model. Our model simulations revealed the prolongation of the action potential, increased [Ca2+]i transients, and generation of pro-arrhythmic events called early afterdepolarizations (EADs) in hypertrophic myocytes as compared to control myocytes. Simulation of the hypertrophic myocyte activities revealed that the synergistic effects of the late Na+ current, the L-type Ca2+ current, and the T-type Ca2+ current were responsible for the initiation of EADs at slow stimulations rates (< 1 Hz) upon application of 1 μM of β-adrenergic agonist isoproterenol.

Speaker 4: Diyora Rakhimova (Georgia State University)

Title: Dynamic Entrainment of Neuronal Models

Abstract: Dynamic entrainment in neuronal systems is key to understanding synchronization in biological processes. This study investigates dynamic entrainment in the Hodgkin-Huxley (HH) and Morris-Lecar (ML) models, which simulate neuronal behavior through nonlinear differential equations. We explore the models' responses to constant and square pulse currents, hypothesizing that constant current leads to stable depolarization, while square pulse currents induce periodic bursts. Numerical simulations were performed to test these hypotheses. The HH model showed continuous action potentials and periodic spikes under constant current, while the ML model exhibited steady membrane potential oscillations. Both models demonstrated periodic bursts under square pulse currents, confirming their ability to synchronize with intermittent stimuli. This research introduces a Dynamic Entrainment technique, identifying optimal time intervals for 1:1 entrainment. These results have implications for understanding synchronization-related disorders, such as epilepsy, and will guide future studies on complex multi-neuron networks.

Speaker 5: Elle Buser (Emory University)

Title: Efficient sampling approaches based on generalized Golub-Kahan methods for large-scale hierarchical Bayesian inverse problems

Abstract: Uncertainty quantification for large-scale inverse problems remains a challenging task. For linear inverse problems with additive Gaussian noise and Gaussian priors, the posterior is Gaussian but sampling can be challenging, especially for problems with a very large number of unknown parameters (e.g., dynamic inverse problems) and for problems where computation of the square root and inverse of the prior covariance matrix are not feasible. Moreover, for hierarchical problems where several hyperparameters that define the prior and the noise model must be estimated from the data, the posterior distribution may no longer be Gaussian, even if the forward operator is linear. Performing large-scale uncertainty quantification for these hierarchical settings requires new computational techniques. In this work, we consider sampling approaches based on generalized Golub-Kahan based methods for large-scale, hierarchical Bayesian inverse problems. We consider a hierarchical Bayesian framework where both the noise and prior variance are modeled as hyperparameters and exploit generalized Golub-Kahan based methods to efficiently sample from the posterior distribution. Numerical examples from seismic imaging, dynamic photoacoustic tomography, and atmospheric inverse modeling demonstrate the effectiveness of the described approaches.

Speaker 6: Emeka Peter Mazi (Georgia State University)

Title: Transform method for modeling erosion in porous media

Abstract: We develop a generalized transform technique to simulate the erosion of a porous medium of multiple cylindrical bodies generated by the singularities of a viscous Stokes flow problem. The flow problem is embedded in a two-dimensional channel, which satisfies the biharmonic equation. The transforms are a generalization of the classical Fourier and Mellin transforms to general circular domains. It is shown, by example, how they can be used to solve boundary value problems for Laplace’s equation. The concept of spectral functions which are the element of the special matrix that satisfy the global relation or equivalently analyticity of function is introduced. Computing the resistance matrix helps to determine the shear stress acting on the cylindrical bodies. Furthermore, we present an idealized mathematical model based on threshold law: erosion occurs when the total shear stress is greater than some specified critical value depending on the material of the cylindrical bodies. Erosion not only diminishes the size of the cylindrical bodies but changes the shapes. In this case, the cylindrical bodies tend to shrink and the bodies vanish in finite time.

Speaker 7: Epherata Zeleke (Emory University)

Title: From Pixels to Patterns: Neural Networks on Display

Abstract: From computer vision to large language models, neural networks and deep learning have revolutionized the types of problems we can tackle with computational mathematics. Neural network models are starting to be used in engineering too, as faster and cheaper simulations for engineering systems. In this project we will learn how neural networks "think." Specifically we will investigate the four ingredients that go into a neural network recipe: architecture, metrics, optimization, and data. This exploratory project will provide a first-look or a refresher on practical uses of linear algebra and multivariable calculus.

Speaker 8: Grant Bruer (Georgia Tech)

Title: Seismic monitoring of CO2 plume dynamics using ensemble Kalman filtering

Abstract: Monitoring carbon dioxide (CO2) injected and stored in subsurface reservoirs is critical for avoiding failure scenarios and enables real-time optimization of CO2 injection rates. Sequential Bayesian data assimilation (DA) is a statistical method for combining information over time from multiple sources to estimate a hidden state, such as the spread of the subsurface CO2 plume. Existing literature in the seismic-CO2 monitoring domain uses small physical systems with unscalable DA algorithms, ignores the CO2 flow dynamics, or simulates seismic data without the wave equation or with unrealistic survey designs. We improve upon existing DA literature in this domain by applying the scalable ensemble Kalman filter (EnKF) DA algorithm to a high-dimensional CO2 reservoir using two-phase flow dynamics and time-lapse full waveform seismic data with a realistic surface-seismic survey design. We show this DA method is more accurate compared to using either the seismic data or the fluid physics alone. Furthermore, we show the stability of this method by testing a range of values for the EnKFhyperparameters and give guidance on their selection for seismic CO2 reservoir monitoring.

Speaker 9: Hamed Karami (Georgia State University)

Title: Exploring fitting and forecasting strategies for the Cholera model; insights from the 1991-1997 Cholera epidemic in Peru

Abstract: Environmental transmission plays a pivotal role in cholera dynamics, influencing the accuracy and utility of epidemiological models. This study explores three distinct scenarios for estimating the environmental transmission rate while concurrently estimating key parameters, such as the reporting rate. Focusing on the 1991–1997 cholera outbreak in Peru, we employ these approaches to calibrate the model and assess its parameter estimates. Additionally, the study extends these methodologies to forecasting cholera cases during this outbreak, with particular attention to the disease's seasonal nature

and its strong correlation with temperature. While forecasting seasonal diseases like cholera poses challenges, even for short-term horizons, we aim to provide reliable predictions by leveraging multiple datasets. The results include several forecasts and an in-depth analysis of cholera trends, offering insights into model performance and practical implications for epidemic preparedness.

Speaker 10: Hao-Ning Wu (University of Georgia)

Title: Breaking quadrature exactness in numerical approximation and numerical methods for PDEs and integral equations

Abstract: Hyperinterpolation is a quadrature-based approximation scheme for continuous functions, which can be viewed as a discrete version of the L^2 orthogonal projection. This scheme features an elegant L^2 convergence theory and is relatively easy to implement. However, its convergence theory heavily relies on specific degrees of quadrature exactness, limiting its applicability in multivariate domains. In this poster, we discuss our recent progress in addressing this limitation by relaxing the quadrature exactness requirement, aided by the Marcinkiewicz--Zygmund inequality. By deriving error bounds for approximation, we can use sets of points that do not necessarily exhibit quadrature exactness for hyperinterpolation, while still maintaining reasonable error rates. Furthermore, we showcase the application of the Marcinkiewicz--Zygmund inequality to quadrature-based numerical methods for solving the Allen--Cahn equation and the Fredholm integral equations of the second kind on spheres. Numerical examples for the resulting numerical approximation and numerical methods are presented.

Speaker 11: Imran Shah (Georgia Tech)

Title: Real-Time Shape Optimization of Patient-Specific Fontan Surgical Planning Procedures via Reduced Order Models

Abstract: Fontan surgical planning via computational fluid dynamics (CFD) has become a well-established paradigm for children born with congenital single ventricle defects, providing clinicians with pre-operative hemodynamic characterization of the Fontan anatomy to optimize surgical outcomes. At its crux, this paradigm represents a shape optimization problem, where different anatomical connections between the hepatic veins and pulmonary arteries result in unique hemodynamics. However, despite its effectiveness in aiding clinical decision-making, the required computational demands are high especially with repetitive CFD analysis of various surgical options in a trial-and-error fashion (up to 48 hours each). To this end, we aim to develop a novel reduced order modeling (ROM) paradigm for Fontan surgical planning cases, which will allow for real-time hemodynamic analysis of patient-specific anatomies. Coupled with trust-region optimization methods and using clinically relevant metrics as the primary criteria, this framework will allow for accelerated and near real-time identification of the optimal surgical option for a given patient.

Speaker 12: Isaac Goodspeed (Georgia State University)

Title: Stress Inference In Retinal Pigment Epithelia

Abstract: Age-related Macular Degeneration (AMD) is the main cause of vision loss in the elderly. The retinal pigment epithelium (RPE) provides metabolic support to photoreceptor cells, and its dysfunction and death are early events in AMD. Observations from animal models and human samples indicate that RPE cells undergo changes in shape, density, and location in AMD. However, little is known about the distribution of mechanical properties in the RPE. To understand stress and pressure distribution in the RPE and its contribution to AMD, we perform tissue stress inference using mouse RPE flatmount images, based on the assumption that the tissue is in mechanical equilibrium. We developed an analysis pipeline

that first uses CellPose and ImageJ to segment individual cells and skeletonize cell boundaries, and then use CellFit to quantify stress and pressure within the tissue. This is the first time tissue stress distribution has been calculated for RPE. We investigated RPE stress patterns between wild-type mice of different age groups, our hypothesis being that aging increases mechanical stress in the RPE and contributes to AMD pathogenesis. Highlighting the importance of mechanical stress in RPE and AMD, our study may suggest new intervention pathways.

Speaker 13: Jiaqi Yang (Emory University)

Title: Multi-patient Computational Analysis of Type B Aortic Dissections

Abstract: Aortic dissection (AD) is a life-threatening condition of the aorta, initiated by a tear in the intimal layer of the aortic wall, allowing blood to penetrate and separate the aortic layers. In type-b aortic dissection (TBAD), the primary intimal tear (PIT) occurs in the descending aorta, distal to the left subclavian artery, resulting in the separation of the aortic wall into a true lumen (TL) and a false lumen (FL). The management TBAD challenges clinicians due to the intricate patient-specific geometry and turbulent blood flow in the arterial branches. Computational fluid dynamics (CFD) simulations were performed on a cohort of sixteen patients retrieved from Emory TBAD database, followed by a comprehensive statistical analysis of both morphological and hemodynamic factors. The objective of this study is to extract risk predictors associated with FL enlargement in patients with TBAD and to develop a potential clinically applicable risk assessment tool to improve TBAD management.

Speaker 14: Judith Ugalde (Georgia Tech)

Title: Mathematical Modeling of Uncertainty in Engineering

Abstract: Computational models or simulations play a key role in predicting the behavior of scientific and engineering systems, enabling scientists and engineers to analyze system performance and make design and policy decisions. However, most systems of interest are subject to many uncertain factors, which can lead to variation in the system behavior. In this project, we will learn how we can model these uncertainties and understand their impact on system behavior using computational methods based on random numbers. This exploratory project will provide a first look or refresher on ideas from probability and statistics and how they are used in engineering and science.

Speaker 15: Justyna Sokolik (Georgia State University)

Title: Mathematical modeling of cell proliferation in a scaffold with elastic branching channels

Abstract: Tissue engineering scaffolds consist of pores lined with cells through which a nutrient-filled fluid passes. Over time, cells consume the nutrients and proliferate, causing the pores to shrink until they completely fill with tissue. Existing literature has investigated the effects of nutrient flow rate, nutrient concentration, cell hunger rate, scaffold elasticity, and shear stress on cell proliferation within cylindrically shaped pores. In this work, we aim to model tissue growth considering all factors simultaneously while utilizing a different scaffold geometry. Specifically, we consider a branching structure; a scaffold which begins as a cylinder but repeatedly bifurcates over the length of the scaffold. Our objectives are the following: (i) develop a model of cell proliferation which includes nutrient flow dynamics and concentration, cell hunger, and scaffold elasticity; (ii) solve the model and then simulate the cell proliferation process; and (iii) optimize the initial configuration of the scaffold channels to maximize the cell growth. The results of this study are key to adapting the

equations governing cell proliferation to more complex geometries, ones which can more accurately represent scaffolds used in experimental tissue engineering.

Speaker 16: Kelley Smith (Georgia State University)

Title: Aperiodic Power and Its Implications for Seizure Onset Zone Detection

Abstract: We parameterize the neural power spectra with a specific focus on the aperiodic component to estimate information flow and infer the excitation-inhibition (E:I) balance between seizure onset zone (SOZ) and non-SOZ regions across interictal, preictal, and ictal states. Specifically, we examine dynamic changes in the 1/f power slope to characterize E:I imbalance and its evolution during the transitions from interictal to preictal and preictal to ictal states. By investigating antagonistic information flow between SOZ and non-SOZ regions, we aim to elucidate how network dynamics shift across these critical epochs.
We validate our approach on a large dataset, demonstrating how the 1/f power slope captures critical differences between SOZ and non-SOZ regions. Dominant information flow from non-SOZ to SOZ regions is analyzed to understand the cascading neural dynamics underlying seizure onset. Additionally, a machine learning algorithm is applied to predict SOZ regions and investigate their relationship with seizure outcomes.
By integrating spectral parameterization, information flow estimation, and machine learning, this study provides a comprehensive framework to decode excitation-inhibition imbalance in epileptic networks and its role in SOZ localization.

Speaker 17: Kevin Slote (Georgia State University)

Title: The Twitter effect: How anti-regulation organizations drive firearm acquisitions in the United States

Abstract: This study originates from our recently submitted research to PNAS Nexus (under review) and seeks to address the causal role of advocacy groups' activity on Twitter and media as drivers of firearm acquisition in the United States. Firearm injuries are a leading cause of death in the United States, where a more significant number of people die by firearms than in motor vehicle crashes. Although firearms present a significant public health risk, Americans continue to purchase them in large amounts. Three drivers of firearm acquisition are commonly cited in the literature, namely fear of violent crime, fear of mass shootings, and panic-buying. Studies have demonstrated causal links between these drivers and firearm acquisition on a weekly scale. In addition, the activity of relevant interest groups on social media, which capitalize on emotions such as fear, may impact impulsive firearm acquisition in the short time scales of days. We analyze how these factors collectively drive firearm purchases, a relationship no study tested using the causal framework PCMCI+.

Speaker 18: Lawan Wijayasooriya (Georgia State University)

Title: Unraveling multiple 1:1 entrainment regions in the Arnold onion diagram: A study of the circadian Novak-Tyson model

Abstract: The entrainment of biological oscillators is a fundamental problem in studying dynamical systems and synchronization. The Arnold onion diagram is a key tool for visualizing entrainment patterns in a two-dimensional parameter space, defined by period (T) and photoperiod (χ). This paper investigates the entrainment behavior of various oscillatory regimes in the Novak-Tyson model. While previous studies have documented the presence of Arnold onions featuring a single 1:1 entrainment region, our work

introduces the novel emergence of multiple disconnected 1:1 entrainment regions within these diagrams. Through the analysis of dynamical systems, we show that for an unforced system near the Hopf bifurcation point, which behaves as a damped oscillator, multiple Arnold onions emerge. These findings offer new insights into the complex mechanisms underlying circadian seasonality and its dependence on intrinsic oscillator dynamics.

Speaker 19: Leonardo Molinari (Emory University)

Title: A Domain Decomposition Framework for Multiphysics Modeling of Cardiac Radiofrequency Ablation

Abstract: Cardiac radiofrequency ablation (RFA) is a key therapeutic technique used to terminate arrhythmias by selectively heating and destroying targeted tissue areas. Accurate RFA modeling is essential for optimizing treatment outcomes and minimizing complications. RFA presents a complex, inherently multiphysics and multidomain problem, but current models often rely on simplified assumptions and one-way coupling or monolithic approaches across heterogeneous domains. This study introduces a comprehensive physics- and domain-decomposition (DD) approach for cardiac RFA modeling, extensible to various tissue types (e.g., kidney, uterine, hepatic) and energy sources (RF, microwave, ultrasound, laser). The model encompasses three primary domains—electrode, fluid, and tissue—and integrates heat transfer, electrostatics, fluid dynamics, and a three-state cell-death model for lesion assessment. Some processes are confined to single compartments (e.g., fluid dynamics in fluid, cell-death in tissue), while others (e.g., electrostatics, heat transfer) are solved across domains. Various DD strategies, including Neumann-Dirichlet and Robin-Robin, are investigated and supported by a rigorous convergence. The scalable, high-order implementation in the MFEM library leverages efficient partially assembled operators for high computational performance. Results demonstrate the model's potential for high-fidelity, efficient simulations in cardiac RFA and beyond.

Speaker 20: Marrium Marrium (Georgia State University)

Title: Aperiodic Power and its Implications for Seizure Onset Zone Detection

Abstract: We parameterize the neural power spectra with a specific focus on the aperiodic component to estimate information flow and infer the excitation-inhibition (E:I) balance between seizure onset zone (SOZ) and non-SOZ regions across interictal, preictal, and ictal states. Specifically, we examine dynamic changes in the 1/f power slope to characterize E:I imbalance and its evolution during the transitions from interictal to preictal and preictal to ictal states. By investigating antagonistic information flow between SOZ and non-SOZ regions, we aim to elucidate how network dynamics shift across these critical epochs.
We validate our approach on a large dataset, demonstrating how the 1/f power slope captures critical differences between SOZ and non-SOZ regions. Dominant information flow from non-SOZ to SOZ regions is analyzed to understand the cascading neural dynamics underlying seizure onset. Additionally, a machine learning algorithm is applied to predict SOZ regions and investigate their relationship with seizure outcomes. By integrating spectral parameterization, information flow estimation, and machine learning, this study provides a comprehensive framework to decode excitation-inhibition imbalance in epileptic networks and its role in SOZ localization

Speaker 21: Mitchell Scott (Emory University)

Title: Acceleration Methods for Scientific and Data Science Applications

Abstract: Neural networks have become ubiquitous in machine learning due to their versatility across tasks, yet their training remains computationally demanding. While first-order optimizers like ADAM are popular, their performance critically depends on careful hyperparameter tuning, which can hinder robustness and reproducibility. To address these challenges, we study the nonlinear Truncated Generalized Conjugate Residual (nlTGCR) method, an optimizer that efficiently utilizes second-order curvature information without requiring explicit Hessian computations. We enhance the original nlTGCR method by incorporating the Fisher information matrix, which improves its robustness across mini-batches and accelerates convergence. Our stochastic convergence analysis confirms the enhanced performance of the Fisher-enhanced nlTGCR method. We support these theoretical findings with numerical experiments, demonstrating improved performance compared to state-of-the-art baselines.

Speaker 22: Paloma Hodje (Georgia State University)

Title: On mathematical modeling of deposition and erosion in porous media with elastic branching channels

Abstract: In this paper, we study the processes of erosion and deposition in porous structures to demonstrate how these phenomena modify the structure of porous media at a pore level using a branching model. These interactions play an important role in scenarios that are of environmental interest, such as soil degradation, as well as in industrial applications including systems of water purification. This paper uses a refined one-dimensional model by taking full advantage of the homogeneity of the medium. We model porosity, shear stress, particle concentration, and elasticity parameters during erosion and deposition by implementing Darcy's law, in the case of fluid flow and advection diffusion reaction equation for nutrient transport. Additionally, the deformation of the medium under shear forces is described by the Navier-Cauchy equation. We use asymptotic analysis based on the porous medium small aspect ratio to simplify our model to derive a reduced model. The erosion and deposition model causes the porous medium to expand due to erosion and shrink due to deposition. We investigate the values of the parameters that lead to specific behaviors and observe how the system evolves due to these actions.

Speaker 23: Phillip Si (Georgia Tech)

Title: Latent-EnSF: A Latent Ensemble Score Filter for High-Dimensional Data Assimilation with Sparse Observation Data

Abstract: Accurate modeling and prediction of complex physical systems often rely on data assimilation techniques to correct errors inherent in model simulations. Traditional methods like the Ensemble Kalman Filter (EnKF) and its variants as well as the recently developed Ensemble Score Filters (EnSF) face significant challenges when dealing with high-dimensional and nonlinear Bayesian filtering problems with sparse observations, which are ubiquitous in real-world applications. In this paper, we propose a novel data assimilation method, Latent-EnSF, which leverages EnSF with efficient and consistent latent representations of the full states and sparse observations to address the joint challenges of high dimensionlity in states and high sparsity in observations for nonlinear Bayesian filtering. We introduce a coupled Variational Autoencoder (VAE) with two encoders to encode the full states and sparse observations in a consistent way guaranteed by a latent distribution matching and regularization as well as a consistent state reconstruction. With comparison to several methods, we demonstrate the higher accuracy, faster convergence, and higher efficiency of Latent-EnSF for two challenging applications with complex models in shallow water wave propagation and medium-range weather forecasting, for highly sparse observations in both space and time.

Speaker 24: Sheriff Akeeb (Georgia State University)

Title: Modeling of Collective Cancer Invasion: Unraveling Leader-Follower Interactions and Dynamics

Abstract: Metastasis, the spread of cancer from a primary tumor to distant sites, is driven by coordinated cell behaviors within the tumor microenvironment. A key mechanism underlying metastasis is collective cancer cell migration, significantly impacting cancer progression and patient outcomes. Experimental studies using spatiotemporal genomic and cellular analysis have uncovered the phenotypic heterogeneity within invading cancer cell populations, distinguishing leader cells—phenotypically stable and highly invasive—from follower cells, which exhibit phenotypic plasticity and limited invasiveness. Despite these advancements, the biophysical properties and interactions governing collective invasion remain poorly understood. To address this knowledge gap, we developed a cell-based computational model based on the cellular Potts model framework to investigate the interplay between leader cell migration, follower cell proliferation, and leader-follower interactions during collective invasion. The model distinguishes between single cell invasion and collective invasion by quantifying invasive area vs. infiltrative area, single vs. clustered cell breakoff, invasive stalk number and height. Our simulations reveal that leader cell migration, leader-follower adhesion, and follower proliferation are critical determinants of collective cancer migration. These findings provide novel insights into the biophysical mechanisms driving collective invasion.

Speaker 25: Sima Moshafi (Georgia State University)

Title: Continuous model for collective invasion with leader-follower dynamics

Abstract: Collective invasion is pivotal in cancer metastasis, characterized by the coordinated movement of leader and follower cells into surrounding tissues. We present a continuous mathematical model to investigate the collective invasion dynamics, focusing on cell migration, leader chemotaxis, cell-cell adhesion, and the conservation of cell numbers. Using a nondimensionalized system of partial differential equations solved numerically via the finite element method, we explored invasion dynamics across diverse parameter settings. Preliminary simulations show leader cells migrating directionally follow a chemoattractant gradient, forming invasion fronts that pull follower cells via strong leader-follower adhesion. Collective invasion is observed when leader-follower adhesion is stronger than leader-leader adhesion. Our results aim to provide early insights into the interplay between chemotaxis and adhesion in driving collective invasion.

Speaker 26: Somiya Rauf (Georgia State University)

Title: Immunogenic cell death: the key to unlocking the potential of combined immunotherapy and radiotherapy in cancer

Abstract: In cancer treatment, immunogenic cell death (ICD) promotes the release of tumor-associated antigens, changes the tumor microenvironment, and activates the anti-tumor immune system response. Here, we develop a mathematical model to determine the role of ICD in enhancing the effectiveness of combined macrophage-based immunotherapy and radiotherapy for cancer treatment. Our model focuses on the SIRPα-CD47 pathway and uses data from preclinical murine models of SIRPα perturbation, with and without local irradiation. We find that radiotherapy invokes minimal ICD in tumors in wild-type mice, and that ICD depends on radiation dose

and tumor size in SIRPα-deficient mice. ICD levels are highest in SIRPα-deficient mice, followed by injection of SIRPα-deficient macrophages in wild-type mice, then treatments of anti-SIRPα, anti-CD47, and finally CD47-knockout. Analysis of the phagocytosis parameter reveals a descending order of phagocytic activity, from SIRPα-knockout, CD47-knockout, SIRPα-deficient macrophage injections, anti-SIRPα, anti-CD47, to wild-type macrophages that show no phagocytosis activity. Furthermore, the ICD and phagocytic activities together suggest a phenotypic span ranging from M1 to M2-like with the perturbations to the SIRPα-CD47 binding.
The model predicts the abscopal effect of the combined radio- and macrophage-based immuno- therapy. We further predict the treatment efficacy given radiation doses,
macrophage phagocytosis capacity, and ICD strength, for various tumor sizes. These results highlight the critical role of ICD in capitulating the efficacy of the combined radio- and immuno-therapies and offer a new framework to better conceptualize and design optimal cancer treatment strategies.

Speaker 27: Tomoki Koike (Georgia Tech)

Title: LyapInf: Data-Driven Lyapunov Function Inference for Nonlinear Stability Analysis

Abstract: In stability analysis of nonlinear dynamical systems, identification of a Lyapunov function---a positive function with non-positive time derivative along system trajectories---provides sufficient conditions for system stability and enables estimation of the system stability region. While analytical Lyapunov functions have been identified for some well-studied low-dimensional dynamical systems, constructing Lyapunov functions for general nonlinear dynamical systems is challenging, and existing methods often rely on explicit knowledge of the system governing equations. In this work, we introduce a new method for inferring a Lyapunov function from system trajectory data that treats the dynamical system as a black box and does not require explicit knowledge of the system governing equations. Our method is based on a result by Zubov which states that a Lyapunov function satisfying a certain first-order partial differential equation (the so-called Zubov equation) provides a characterization of the full domain of attraction of the system. In our Lyapunov function inference method (LyapInf), we propose a quadratic ansatz for the unknown Lyapunov function and fit the unknown quadratic operator to system trajectory data by minimizing the average residual of the Zubov equation over the data. Numerical results on benchmark examples demonstrate that LyapInf successfully identifies Lyapunov functions associated with near-maximal ellipsoid estimates of the system domain of attraction.

Speaker 28: Vladimir E Bondarenko (Georgia State University)

Title: Mechanism of EADs in Hypertrophic Mouse Ventricular Myocytes

Abstract: NA

Speaker 29: Wilbur Hudson (Georgia State University)

Title: Rapid Identification of Antibiotic Resistance in Staphylococcus Using FTIR and Machine Learning

Abstract: Antimicrobial resistance (AMR) poses a significant threat to global health, with Methicillin-resistant Staphylococcus aureus (MRSA) contributing substantially to morbidity. Rapid identification of MRSA versus Methicillin-susceptible S. aureus (MRSA) is critical for timely and appropriate antibiotic use.

This study explores the use of Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) on Fourier Transform Infrared (FTIR) spectroscopy data to quickly distinguish MRSA from MSSA. By analyzing the growth patterns and spectral data of SA6538 (MSSA) and SA43300 (MRSA) under antibiotic stress, we demonstrate the feasibility of separation, highlighting spectral differences and their likely biological causes. LDA, when applied to primary, secondary, and tertiary FTIR datasets, achieves high classification accuracy, particularly when initially processed with PCA. This combined approach suggests a rapid and reliable diagnostic method to improve clinical outcomes and curb the spread of AMR.

Speaker 30: Xavier Sodjavi (Georgia State University)

Title: Jet formation during drop impact

Abstract: High-speed liquid jets, commonly observed during droplet impacts, exhibit complex morphologies influenced by initial conditions, fluid properties, and system geometry. These jets play a critical role in applications such as inkjet printing, pesticide spraying, fuel combustion, and air-sea gas exchange, where their behavior can either enhance or impede desired outcomes. Accurately predicting jet characteristics—such as thickness, velocity, and stability—remains a significant challenge due to the intricate interplay of momentum transfer and energy dissipation. This research combines three-dimensional numerical simulations with experimental analysis to investigate jet morphologies in a simplified system. The experimental setup, consisting of two rapidly converging plates, eliminates complexities associated with droplet impacts while retaining key fluid dynamics. High-speed imaging provides experimental validation of the initial numerical simulations, revealing promising alignment and enabling a comprehensive parametric study. Additionally, the project aims to explore the control parameters in depth to uncover new morphologies and generate sufficient data to enhance our physical understanding of these phenomena. These insights will aid in the development of advanced predictive models for effectively controlling jet behavior across diverse engineering and industrial applications.

Speaker 31: Xuyang Sun (Georgia State University)

Title: Closing the Gap: Cell-Based Modeling of Epithelial Wound Healing with Fibroblasts

Abstract: Wound healing, an important physiological reaction to tissue injury, involves intricate interactions across multiple scales, between numerous cell types, cytokines, and the extracellular matrix (ECM). While many previous studies of wound healing focused on the biochemical factors and cellular responses, much remains to be understood about the biophysical roles of the ECM. This project aims to develop a multiscale cell-based epithelial model to study the role of ECM in wound healing. We use the cellular Potts model within the Compucell 3D framework and simulate epithelial, fibroblast, and myofibroblast.TGF-β induces chemotaxis in fibroblasts, guiding their movement toward the wound and driving their differentiation into myofibroblasts. Myofibroblasts secrete ECM, promoting tissue contraction and wound closure. The ECM, explicitly modeled as a separate fiber network beneath the cells, not only provides structural support but also regulates epithelial cell proliferation and motility through haptotaxis cues. In this model, fibroblasts interact with the ECM to release active TGF-β, establishing the main source of TGF-β in the wound microenvironment. By modulating the properties and spatial distribution of active TGF-β, we simulate various scenarios to explore how different TGF-β dynamics affect wound healing outcomes. Overall, this approach enables us to investigate wound closure mediated by fibroblasts and the ECM while testing hypotheses about fibroblast differentiation, ECM biophysics, and the mechanisms that regulate the resolution of wound healing.

Speaker 32: Ye Haochen (Georgia State University)

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Speaker 33: Yunho Kim (Ulsan National Institute of Science and Technology)

Title: Analysis for reservoir computing with applications in image processing

Abstract: RC (Reservoir Computing) is one of the state-of-the-art machine leaning methods. This architecture was proposed in the early 2000's in two forms after experimental observations about the training nature of RNNs. One is ESNs (Echo State Networks) and the other is LSMs (Liquid State Machines). While it was meant for time-series or sequential datasets, we present its applicability to non-sequential datasets such as static images. We also provide analysis about what influences the performance of RC.

Speaker 34: Zhaiming Shen (Georgia Tech)

Title: The Kolmogorov Superposition Theorem can Break the Curse of Dimensionality When Approximating High Dimensional Functions

Abstract: We explain how to use Kolmogorov Superposition Theorem (KST) to break the curse of dimensionality when approximating a dense class of multivariate continuous functions. We first introduce a dense class of continuous functions called Kolmogorov-Lipschitz (KL) continuous in $C([0,1]^d)$ which can be approximated by a special ReLU neural network of two hidden layers with a dimension independent approximation rate $O(1/n)$, where n is the total number of neurons for each component of the input variable. We also show that the approximation constant is increasing quadratically in the dimension d, and the number of parameters used in such neural network approximation equals to $O(nd)$. Next, we introduce KB-splines by using linear B-splines to approximate the outer function and smooth the KB-splines to have the so-called LKB-splines as the basis for approximation. Our theoretical and numerical results show that the curse of dimensionality is broken in the following sense: When using the standard discrete least squares (DLS) method to approximate a continuous function, there exists a pivotal set of points in $[0,1]^d$ with size at most $O(nd)$ such that the rooted mean squares error

(RMSE) from the DLS based on the pivotal set is similar to the RMSE of the DLS based on the original set with size $O(n^d)$. The pivotal point set is chosen by using matrix cross approximation technique and the number of LKB-splines used for approximation is the same as the size of the pivotal data set. Therefore, we need neither many basis functions nor many function values to approximate a high dimensional continuous function.