I-DISC STUDENT POSTER SESSION (4.26.24)

(Research authors: Only the **students presenting** indicated in bold type, and the I-DISC Faculty Member Advisers are listed below).

1. "Stochastic Methods for Multi-Level Multi-Objective Optimization"

Griffin D. Kent, PhD Student & **Tommaso Giovannelli ,** Postdoc, Industrial & Systems Engineering
I-DISC Faculty Member Adviser: Luis Nunes Vicente, Industrial and Systems Engineering Department
The goal of this work is to propose efficient bilevel stochastic gradient (BSG) descent algorithms for bilevel, trilevel, bilevel multi-objective, and mixed-integer bilevel optimization problems. Provide a unified convergence theory of the proposed methods – for both the constrained and unconstrained cases – that addresses all forms of inexactness in the computation of the adjoint gradient. Develop two new risk-neutral and risk-averse interpretations of the bilevel multi-objective problem. Demonstrate the practical performance of the proposed algorithms on both synthetic problems and large-scale machine learning problems.

2. "Underdog Achievement and Randomness in Team Ball Sports"

Thaksheel Alleck, UG, Industrial & Systems Engineering & Marketing
I-DISC Faculty Member Adviser: Luis Nunes Vicente, Industrial and Systems Engineering Department and Outreach ISE Program

In this paper, we examine team ball sports to investigate how the likelihood of weaker teams winning against stronger ones, referred to as underdog achievement, is influenced by inherent randomness factors in such sports. To address our research question, we collected data on match scores and computed corresponding team rankings from major international competitions for~12 popular team ball sports: basketball, cricket, field hockey, futsal, handball, ice hockey, lacrosse, roller hockey, rugby, soccer, volleyball, and water polo. Then, we developed an underdog achievement score to identify the sports with the highest and lowest occurrences of weaker teams prevailing over stronger ones, and we designed a randomness model consisting of factors that contribute to unexpected game outcomes within each sport. Our findings indicate that soccer is the sport in which a weaker team is most likely to win. Through principal component analysis, we demonstrate that our randomness model can explain such a phenomenon, showing that the underdog achievement can be attributed to numerous factors that may randomly influence a team's performance.

3. "Global CBDC Consensus: Hierarchical Stellar Consensus Protocol"

Luke Hale, Graduate student, Computer Science; **Yiannis Karamitros,** UG, Computer Science; **Zeeshan Khan,** UG, Computer Science; **Adrian Ross,** UG, Computer Science & Business
I-DISC Faculty Member Adviser: Henry F. Korth, Computer Science & Engineering

Numerous national central banks are considering and/or prototyping central-bank digital currencies (CBDC). The largest, the e-CNY, has a high degree of central control. This research addresses the widely perceived need to decentralize control of a global currency for reasons that include privacy and national/regional autonomy. We present a consensus scheme in which independently operating distributed consensus processes reach consensus among themselves via a hierarchical consensus algorithm. We also address the management of global transactions in a manner compatible with the concept of independent consensus domains. We are building a prototype using the Stellar blockchain and its Soroban smart-contract language. Stellar is a good starting point because the Stellar Consensus Protocol is based on extending local trust to global consensus, making it the blockchain consensus algorithm most directly adaptable to the global CBDC problem.

4. “Associating Genes with Diet through Convergent Evolution”

Michael Tene, Graduate Student, Biology
I-DISC Faculty Member Adviser: Wynn K. Meyer, Biological Sciences

By examining the genes with common patterns of relative evolutionary rate across independent replicates of evolution, we can detect genes which are associated with the evolution of the trait. Using this method, we have identified several genes and pathways associated with diet evolution in mammals. Our work is focused on the evolution of carnivory, and we have additionally examined the evolution of omnivory and herbivory.
We have found metabolic genes to be evolving at different rates in carnivores and herbivores. Amino acid and lipid metabolism evolve more slowly in carnivores than herbivores. We find genes in the smell and taste pathways to be evolving faster in carnivores than herbivores. We find mitochondrial respiration to be evolving faster in omnivores than all other diets.

5. “Incorporating Domain Differential Equations into Graph Convolutional Networks to Lower Generalization Discrepancy”

Yue Sun, Graduate Student, Electrical Engineering
I-DISC Faculty Member Advisers: Rick S. Blum, Parv Venkitasubramaniam, Electrical & Computer Engineering

Ensuring both accuracy and robustness in time series prediction is critical to many applications, ranging from urban planning to pandemic management. With sufficient training data where all spatiotemporal patterns are well-represented, existing deep-learning models can make reasonably accurate predictions. However, existing methods fail when the training data are drawn from different circumstances (e.g., traffic patterns on regular days) compared to test data (e.g., traffic patterns after a natural disaster). Such challenges are usually classified under domain generalization. In this work, we show that one way to address this challenge in the context of spatiotemporal prediction is by incorporating domain differential equations into Graph Convolutional Networks (GCNs). We theoretically derive conditions where GCNs incorporating such domain differential equations are robust to mismatched training and testing data compared to baseline domain agnostic models. To support our theory, we propose two domain-differential-equation-informed networks called Reaction-Diffusion Graph Convolutional Network (RDGCN), which incorporates differential equations for traffic speed evolution, and Susceptible-Infectious-Recovered Graph Convolutional Network (SIRGCN), which incorporates a disease propagation model. Both RDGCN and SIRGCN are based on reliable and interpretable domain differential equations that allow the models to generalize to unseen patterns. We experimentally show that RDGCN and SIRGCN are more robust with mismatched testing data than the state-of-the-art deep learning methods.

6. “Immune Cell Classification”

Deven Bhadane, Graduate Student, Computer Science
I-DISC Faculty Member Adviser: Dr. Yaling Liu, Bioengineering and Mechanical Engineering & Mechanics

Lymphocytes cells like B, T-4 and T-8 cells plays a pivotal role in protecting the body against a wide range of pathogens, viruses and bacteria, as well as abnormal cell growth like cancer. A deep learning based approach to classification of these 3 different types of lymphocytes cells can help with early disease detection, automation and scalability and real-time diagnosis. We trained a few ResNet models using knowledge distillation and MixUp to achieve an accuracy of 90-95%.

7. "NaVIP: An Innovative Image-Based Solution of Indoor Navigation for Visually Impaired People"
Jun Yu, Graduate Student , Computer Science and **Yifan Zhang**, Grauate Student, Computer Science
I-DISC Faculty Member Adviser: Vinod Namboodiri, Department of Computer Science and Engineering, and College of Health

Indoor navigation is challenging since satellite signals, e.g., GPS, are unavailable for localization. Other sensor signals (e.g., Bluetooth, WiFi, LiDAR, NFC, etc.) come into play and enable a \textit{turn-by-turn} navigation with position updates for users. However, for Visually Impaired People (VIPs), a low-income group, these multi-platform/-device/-sensor solutions are expensive and lack the advanced assistance and intelligence required for confident exploration or self-learning of their own needs. We shift research interests from sensor integration towards vision intelligence, which is infrastructure-free and task-scalable and can assist VIPs in exploring their surroundings and even building a mental map of the areas. We emphasize the importance of an intelligent system to care for VIPs rather than command them. Specifically, we start from curating a large-scale multimodal camera data in a four-floor research building, with \$300\$k images, to expedite the research process of customizing indoor navigation for VIPs. Every image is labeled with precise 6DoF camera poses, details of PoIs, and \$6\$ descriptions to help VIPs in three-level needs (perception, self-learning, and social interaction). We benchmark on two main aspects: (1) positioning system and (2) exploration support, with prioritizing training scalability and real-time inference.

8. "An Iterative Approach for Heterogeneous Multi-Agent Route Planning with Temporal Logic Goals and Travel Duration Uncertainty"
Kaier Liang, Graduate Student, Mechanical Engineering
I-DISC Faculty Member Adviser: Cristian-Ioan Vasile, Mechanical Engineering & Mechanics

This paper introduces an iterative approach to multi-agent route planning under chance constraints. A heterogeneous team of agents with various capabilities is tasked with a Capability Temporal Logic (CaTL) mission, a fragment of Signal Temporal Logic.

9. "AI-powered Robotic Composer and Pianist" - with demonstration
Nolan Jetter, UG Mechanical Engineering, and **Athanasios Cosse,** UG, Mechanical Engineering
I-DISC Faculty Member Adviser: Ebru Demir, Mechanical Engineering & Mechanics

The art of both producing music and subsequently carrying out this creation are inherently human—and thus the whole of the process can be taken as a fundamentally creative process. A musical piece is composed using both established rules and phrases, but also would undoubtedly be incomplete without the human aspects. The emotion, style, and interpretation imbued in a song is fundamentally what makes music meaningful. However, there are also rote and repetitive parts to music that can be automated away with technology. This project explores the components of this automation and its relationship to music. We design three independent components: a pair of robotic biomimetic hands controlled along the length of the piano via a linear actuator system, a generative AI model that is capable of producing new music from a randomized sequence of input data, and a reinforcement learning model that predicts the optimal actions for the robot to take given the desired sequence of notes to be played. By training the reinforcement learning model on both generated musical sequences and random sequences, as well as in a simulation space and on the robot, we provide the model ample opportunity to optimize its playing patterns. Combining these components allows us to produce a robotic system that feels fundamentally quite human and creative, but is undoubtedly missing what makes a human human.

10. “Geometric Analysis of Manifold Clustering Models”

Nimita Shinde, Postdoc, Industrial & Systems Engineering

I-DISC Faculty Member Adviser: Daniel P. Robinson, Industrial & Systems Engineering

Manifold clustering has become an important unsupervised learning tool for video and image processing and interpretation. Often it is assumed that the high-dimensional input data (such as images) lie in low-dimensional non-linear manifolds. Two common approaches to this problem are (1) linear clustering: to represent a data point as a linear combination of other input data points, and cluster using k-means, (2) neural-network-based methods. When the manifolds are linear, linear clustering methods have a well-established theoretical analysis and geometric understanding. However, computationally, these methods do not perform as well as the neural-network-based methods. On the other hand, neural-network-based (state-of-the-art) methods have the current best-known performance, but they lack rigorous theoretical analysis. In our work, we propose a variant of “linear” clustering model, provide geometric analysis of the model and compare its numerical performance with existing methods. While our method does not perform as well as neural-network-based methods, we are able to provide theoretical analysis of the model. Finally, comparing our model with existing linear clustering methods, we show that our method has a better computational performance while also providing geometric analysis.

11. "Optimal Control Synthesis with Relaxed Global Temporal Logic Specifications for Homogeneous Multi-robot Teams"

Disha Kamale, Graduate Student, Mechanical Engineering

I-DISC Faculty Member Adviser: Cristian-Ioan Vasile, Mechanical Engineering & Mechanics

In this work, we address the problem of control synthesis for a homogeneous team of robots given a global temporal logic specification and formal user preferences for relaxation in case of infeasibility. The relaxation preferences are represented as a Weighted Finite-state Edit System and are used to compute a relaxed specification automaton that captures all allowable relaxations of the mission specification and their costs. For synthesis, we introduce a Mixed Integer Linear Programming (MILP) formulation that combines the motion of the team of robots with the relaxed specification automaton. Our approach combines automata-based and MILP-based methods and leverages the strengths of both approaches, while avoiding their shortcomings. Specifically, the relaxed specification automaton explicitly accounts for the progress towards satisfaction, and the MILP-based optimization approach avoids the state-space explosio associated with explicit product-automata construction, thereby efficiently solving the problem. The case study highlights the efficiency of the proposed approach.

12. "ALock: Asymmetric Lock Primitive for RDMA Systems"

Amanda Baran, Graduate Student, Computer Science

I-DISC Faculty Member Adviser: Roberto Palmieri, Computer Science & Engineering

Remote direct memory access (RDMA) networks are being rapidly adopted into industry for their high speed, low latency, and reduced CPU overheads compared to traditional kernel-based TCP/IP networks. RDMA enables threads to access remote memory without interacting with the host, hence complicating synchronization significantly. We introduce ALock, a novel lock primitive designed for RDMA-based systems. We draw inspiration from the classic Peterson’s algorithm to create a hierarchical design that includes embedded MCS locks for two cohorts, remote and local. In workloads with a majority of local operations, the ALock outperforms competitors up to 29x and achieves a latency up to 20x faster.

13. "Physics-informed Inductive Graph Neural Network For Ice Layer Thickness Prediction"
Zesheng Liu, PhD Student, Computer Science & Engineering
I-DISC Faculty Member Adviser: Maryam Rahnemoonfar, Computer Science & Engineering, and Civil & Environmental Engineering

Studying ice layer thickness reveals climate trends, how snowfall has changed over time, and the trajectory of future climate and precipitation. By combining graph convolution operator with a recurrent neural network, the model can learn both spatio and temporal features of ice layers. GraphSAGE, an inductive framework that samples and aggregates features to generate node embedding, outperforms the graph convolution network (GCN) in learning spatio features. Physics-informed learning is a technique that introduces physical constraints to machine learning models for more accurate results. We propose physics GraphSAGE-LSTM, a physics-informed inductive framework that incorporates physical observations as additional node features, and show that it can achieve consistently high performance for ice layer tracking.

14. "**Graph Convolutional Network as a Fast Statistical Emulator for Numerical Ice Sheet Modeling"**
Younghyun Koo, Postdoc, Computer Science & Engineering
I-DISC Faculty Member Adviser: Maryam Rahnemoonfar, Computer Science & Engineering, and Civil & Environmental Engineering

The Ice-sheet and Sea-level System Model (ISSM) provides numerical solutions for ice sheet dynamics by using finite element and fine mesh adaption. However, considering such numerical modeling is compatible only with central processing units (CPU), the ISSM has limitations on further economizing computational time. Several deep learning models have been used to speed up ice sheet modeling based on graphic processing units (GPU), most of which have relied on convolutional neural network (CNN) architectures. However, since CNN is specialized for regular grids, it is not appropriate for the unstructured meshes of ISSM. Therefore, instead of traditional machine learning architectures, we develop a graph convolutional network (GCN) to fully replicate the adapted mesh structures of the ISSM. When applied to the 20-year transient simulations of the Pine Island Glacier (PIG), Antarctica, GCN successfully reproduces ice thickness and velocity, outperforming the baseline non-graph deep learning models, including CNN and multi-layer perceptron (MLP). In particular, compared to the fixed-resolution approach of CNN, the flexible-resolution structure of GCN allows for capturing detailed ice dynamics in fast-ice regions accurately. Additionally, our GCN emulator shows 60-100 times faster computational time than the ISSM by leveraging GPUs.

15. "**An Improved Physics-based Hurricane Track Model for the North Atlantic Basin"**
Chao Sheng, Postdoc, Catastrophe Modeling Center, Civil & Environmental Engineering
I-DISC Faculty Member Adviser: Paulo Bocchini, Catastrophe Modeling Center, ATLSS Engineering Research Center

The present study developed a physics-driven track model for the North Atlantic (NA) basin, which captures explicitly the effects of a comprehensive set of environmental variables.

16. "Data-Driven Design of Next-Generation Quantum Materials"
Srihari Kastuar, Graduate Student, Physics
I-DISC Faculty Member Adviser: Chinedu Ekuma, Physics

Unlocking the potential of quantum materials demands innovative approaches. This poster presents diverse projects leveraging data-driven methodologies to design novel quantum materials with tailored electronic, optical, and topological properties. Through computational simulations and machine learning techniques, we explore the tunability of two-dimensional materials for applications spanning photovoltaics, spintronics, and beyond. From enhancing charge transport in solar cells to harnessing exotic topological phases for quantum information processing, our research aims to revolutionize material discovery.

17. "Computational Design of Hybrid Materials"

Anthony C. Iloanya, Graduate Student; **Guor Jana,** Postdoc; **Yongtai Li,** Graduate Student; **Chidiebere I. Nwaogbo,** Graduate Student; Computational Materials Group, Department of Physics
I-DISC Faculty Member Adviser: Chinedu Ekuma, Physics

Functionalization of two-dimensional materials is crucial for device integration and chemical intercalation of offers an efficient strategy to both tune and control the properties of layered materials. Herein we demonstrate the design of atomically thin GeS with strongly correlated organometallocene such as chromocene. We achieve superior optoelectronic features which are further enhanced by the introduction of 2% vacancy using TMDCA.

18. "OCToPus: Semantic-aware Concurrency Control for Blockchain Transactions"

dePaul Miller, Graduate Student, Computer Science & Engineering
I-DISC Faculty Member Advisers: Hank Korth and Roberto Palmieri, Computer Science & Engineering

Many blockchain implementations offer APIs to send and receive money between accounts exclusively. In this paper, we introduce OCToPus, a deterministic concurrency control scheme that uses a semantic-aware fast path and a GPU-accelerated directed acyclic graph-based fallback path to parallelize the execution of a block aggressively.

19. **"Spatio-Temporal Dynamics Of Avian Influenza: Understanding Avian Influenza Transmission Via Mallard Migration Data"**

Sena Mursel , PhD Student, Civil & Environmental Engineering
I-DISC Faculty Member Advisers: Brian D. Davison, Computer Science & Engineering; Thomas McAndrew, Community & Population Health; Bilal Khan, Community & Population Health; Paolo Bocchini, Civil & Environmental Engineering

Influenza presents a substantial public health concern due to its capacity to trigger extensive epidemics and global pandemics. Interestingly, there remains a significant knowledge gap concerning the mechanisms that sustain the survival and proliferation of these viruses within their natural avian reservoirs. Our study adopts a compartmental SIR model with spatial spread to investigate the dynamics of AIVs in mallard populations. We focus on a geographic region near the Prairie Band Potawatomi Nation in Kansas, chosen for its relevance to underrepresented communities affected by higher disease incidence. We utilized the eBird database, which provides comprehensive weekly bird species abundance data. We collected weekly mallard population data from 441 grid points, covering our study area. This data was extracted for the year 2020 and extended to include 2021. The key results from our analyses show that over 70% of the time period studied, total population density and total infected population density showed opposite trends; the variation of model parameters affect the results meaningfully; regular data collection for mallards is crucial for more precise scenarios; the introduced framework has the potential to be expanded to other geographic locations. Relying solely on total mallard density as a reliable proxy for assessing the spillover hazard is inadequate. Sensitivity analysis indicates the need for improved data collection to estimate infection and recovery rates accurately in wild bird populations. High temporal resolution data gathering is crucial for precise insights into infectious disease dynamics. The presence of multiple local maxima in infected mallard density shows the importance of continuous wildlife surveillance, urging public health authorities to remain vigilant.

20. "Leveraging Neural Operators for Precise Estimation of Greenland's Ice Sheet Layers"

Heling Wang, Graduate Student, Electrical Engineering
I-DISC Faculty Member Adviser: Maryam Rahnemoonfar, Computer Science & Engineering, and Civil & Environmental Engineering

This study explores the application of advanced neural operators to model the complex dynamics of the Greenland ice sheet, a critical component in understanding global climate change. Leveraging a comprehensive dataset derived from Synthetic Aperture Radar (SAR) observations, we implement neural operator models that outperform traditional computational methods in handling the spatial and temporal complexities of cryospheric data. Our findings demonstrate significant improvements in predictive accuracy and model efficiency. Future work aims to integrate multi-resolution datasets and refine model architectures to enhance predictive capabilities further and expand their applicability in climate science. This research not only advances our understanding of ice sheet dynamics but also contributes to the broader field of environmental modeling.

21. "The Effects of Cognitive and Motor Effort on Voluntary Task Choice"

Jack Tully, UG Student, Cognitive Science
I-DISC Faculty Member Adviser: Kate Arrington, Psychology

In recent years, humans have significantly increased the amount of time they spend engaging with digital and virtual environments. Frequently, these environments, like computer displays, offer a variety of task choices for users (Email, web-browsing, media, etc.) encouraging frequent task switching. This uptick in screen-time calls for research examining the underlying processes driving our decisions to move between tasks in a digital ecosystem. Research executed during this honors project will investigate how both physical and cognitive effort influence users' decisions regarding task selection. Using a touch screen display for response collection, we will focus on how predictable increases in reaching distance and visual search difficulty affect the frequency of voluntary task switching. Results from this study will help demonstrate how our decision making is affected by common environmental factors such as changes in effort demand and sensory stimulation.

22. "**Perceptions of AI-Generated Artwork"**

Cindy Tran, UG Student, Cognitive Science
I-DISC Faculty Member Adviser: Catherine M. Arrington, Psychology

AI-generated art has emerged as a novel and disruptive force within the art and design world, challenging traditional notions of authorship and creativity. This phenomenon has generated a spectrum of opinions, reflecting polarized discourse within the art community and beyond. For my senior thesis, I studied the perceptions and opinions of AI-generated art and analyzed how art is perceived by comparing responses to AI-generated art and human-generated art through the utilization of online surveys. As AI continues to push the boundaries of creative expression, this research will provide valuable insights into the evolving relationship between technology, creativity, and the human experience.