2024 Research Tracks

Track 1 – Bionic Creatures

Taking Inspiration From Nature for Innovative Engineering

Disciplines: Mechanical Engineering, Materials Science, Soft Robotics, Biomanufacturing, Collective Motion

Over millions of years, animals and plants have evolved to adapt to their environments to overcome harsh conditions. Patterns and structures from nature inspire engineers as they work to come up with innovative solutions to solve real-world problems. From understanding how geckos climb on smooth surfaces, to learning how to create insect-inspired robots that can cross uneven terrain, to testing the abilities of artificial muscles, researchers are breaking barriers with the help of nature to revolutionize the way robots adapt and interact with the environment. This course will explore the intersection of mechanical engineering and biology, exposing students to interdisciplinary thinking and scientific discovery. Students will investigate case studies that explore themes of locomotion, animal swarms, and bioinspired materials. They will also apply engineering principles to identify organisms with interesting features and translate them into a bioinspired design with a positive societal value.

Track 2 – Social Chemistry

Exploring the Human Connection Through Digital Community and Identity

Disciplines: Communication, Sociology, Psychology, Social Movements, Online Communities

Hashtags such as #TakeAKnee, #MarchforOurLives, and #WomensMarch are critical in the spread of information that floods social media platforms like Instagram, Reddit, X (Twitter), and TikTok. Understanding the intricate interplay between community formation and the digital world is vital to determining how media has altered our everyday experience of social life. This course will focus on byproducts of online social connections at the global, group, and individual levels utilizing social identity theory to understand online life and its impact offline. Students will investigate how online communities tap into users' unique social identities to foster collaboration and action in a digital environment. By studying prominent case studies, such as Black Lives Matter, "r/CovidLongHaulers", and #MeToo, and through examining community building that occurs both offline and online, students will gain an understanding of the socio-cultural implications of networking platforms and how they are driving modern social change.

Track 3 – Decoding Bias

Investigating Media Narratives Through Data Science

Disciplines: Data Science, Communication, Media Studies, Natural Language Processing, Information Theory

Recent studies show that media representation of individuals with marginalized identities (e.g., gender, racial, political) is often subject to biased and stereotypical portrayals. How do such mischaracterizations influence the way we consume entertainment, news, or social media content? What is the impact of these narratives on our individual and collective opinions? This data science course provides students with the necessary theoretical and methodological frameworks for conducting empirical assessments of representation biases in media content. Students will engage in data collection, wrangling, and preparation procedures, analyzing multimodal data via traditional and computational content analytic techniques. In doing so, students will also develop practical skills in natural language processing and computer vision frameworks via the Python programming language. The course will emphasize real-world scenarios, helping students contextualize their scientific quantification of media biases in ways that have direct implications for media policy, journalism practices, as well as academic literature.

Track 4 – Resistance is Futile

Developments in the Fight Against Antibiotic Resistance in Bacteria

Disciplines: Microbiology, Medicine, Computational Biology, Biophysics, Immunology

Millions of strains of bacteria live among us but the majority are harmless to humans. However, disease-causing bacteria, such as *Vibrio cholerae* (cholera) and *Yersinia pestis* (plague), can have devastating effects on human health. The advent of antibiotics drastically reduced the deadly outcomes of these diseases and many more. Subsequently, the boom of antibiotics placed a selective pressure on the most drug-resistant bacteria to thrive. And now, our development of novel classes of antibiotics is being lapped by forms of drug resistance. In this course, students will learn about the microbial world of bacteria, scientific approaches to designing novel drugs, and the triumphs and failures of current clinical treatments for infections. They will explore bench science research techniques like bacterial cell culture and microscopy, as well as silico techniques of modeling trends in disease outbreaks and drug resistance to investigate strategies for combating public health threats.

Track 5 – Legal Labyrinth

Interrogating American Politics through Secularism and Religion

Disciplines: Political Science, Religious Studies, History, Philosophy, Law

The role of religion in the United States government has been contested since the founding of the country. The nation's founders sought a separation between church and state but in recent years, the tension between the religious and the secular has become more apparent in partisan politics, raising questions about how religion affects the structures and procedures of Congress, the Supreme Court, and the Executive Branch. This course explores how the idea of religion—rather than the beliefs of individuals—and the political doctrine of secularism influence court cases, elections, policy decisions, public opinion, and American culture. By using an interdisciplinary approach, students will research the mix of religious and secular ideas that inform American governance, law, and politics. They will explore how the nuances of religious and secular thought have shaped the US, both historically and presently, sometimes in plain sight, and other times in ways that are difficult to see.

Track 6 – Making Bio-Sense

Improving Biosensors Through Biological Tools and Empirical Measurements

Disciplines: Bioengineering, Medicine, Chemical Engineering, Environmental Science, Software Engineering

Every day, we take for granted our body's ability to turn chemical interactions into usable information in our brains. What if we could figure out a way to do this quantitatively for any target or combination of targets that we want to measure? Biosensing allows manmade technology to take advantage of nature's highly evolved mechanisms to quantify small molecular targets, DNA, and even whole cells. In this course, students will explore modern developments in biosensing technologies to identify what makes a good sensor. They will learn about mechanisms for quantification, identify the sensing platforms that currently exist, and examine their real-world implementations. Students will apply these techniques to a variety of current sensing platforms and investigate concepts such as sensitivity vs. selectivity, free energy, and the target binding mechanism. Additionally, they will have the opportunity to use techniques such as electrochemistry and circular dichroism to explore methods for sensor optimization.

Track 7 – Our Burning Planet

Addressing the Human Dimensions of the Climate Crisis

Disciplines: Anthropology, Ecology, Political Science, Environmental Science, History

Climate change is a global story that is both physical and visceral, connecting the future with the past. The story is one of fires, famines, and floods, but also of imperialism, inequality, and poverty that together shape when, why, and where these crises land, and how they are experienced when they do. When a crisis touches everything, how can we research it scientifically, and how can we communicate that science effectively? Should the different threads of climate change be untangled and, if so, how can one do so honestly and ethically, without erasing people, places, species, and histories from the narrative? This course will equip students to address the methodological, theoretical, practical, and emotional challenges of researching and communicating the climate crisis. Students will critically engage with the science of climate change from a range of disciplines and learn how to publish their findings in public media.

Track 8 – Mind the [Health] Gap

Analyzing Health Disparities with the Social-Spatial Determinants of Health

Disciplines: Geography, Demography, Public Health, Sociology, Social Epidemiology

The average life expectancy at birth in the US is about 76 years. However, this number varies significantly based on one's zip code. There are also substantial differences in health outcomes across different countries, states, counties, and even neighborhoods. These disparities start in utero and continue through old age, and surprisingly, these differences are largely driven by factors other than individual health behaviors such as smoking and alcohol use. Researchers define the drivers of these disparities as the social-spatial determinants of health. These are mechanisms through which the places where we live, work, and play influence our health throughout our lives. In this interdisciplinary course, students explore critical concepts from fields like demography, health geography, and public health to understand these gaps. They will also have the unique opportunity to practice data visualization along with analytical techniques, such as cross-sectional data analysis, to investigate health disparities in various contexts.

Track 9 – Vital Code

Probing the Dynamics Between Nuclear and Mitochondrial Genomes

Disciplines: Genetics, Molecular Biology, Mitochondrial Disease, Speciation, Medicine

About 2 billion years ago, eukaryotic cells encountered and engulfed a symbiotic friend in the form of mitochondria, which has its own code. With two independent genomes encoding proteins in cells, studying the dynamics of this unique relationship is critical to understanding evolution and disease. In this course, students will investigate the mechanisms that regulate mitochondrial and nuclear genome activity by diving into how the genotype of one influences the expression of the other. Using the well-characterized model organism, C. elegans, students will employ genetics techniques such as generating stable strains, RNAi gene knockdown, and phenotypic and fluorescence-based analyses to learn what the impacts of the interaction between our nuclear and mitochondrial genomes have on aging, cancer, mutations, and apoptosis. By the end of the course, students will understand how genetics-based inquiries are addressed and get real answers to current questions in the field of mitochondrial genetics.

Track 10 – Data Beneath

Diving Into Marine Conservation Challenges Through Open Source Data Analysis

Disciplines: Marine Biology, Data Science, Ecology, Conservation, Environmental Science

As humans continue to impact the environment, scientists are seeking to gain insight into the changes observed on our planet using unexplored ecological data. This large amount of oceanographical, climatological, and biogeographical information can be used to answer questions that advance climate change mitigation, sustainability, and conservation efforts using proficient computational tools. This course will dive into the data science of marine ecology to examine a series of conservation challenges and identify patterns within the data to improve our understanding of marine system dynamics. Students will examine data sets to explore topics like the impact of climate change on marine systems, ocean acidification, and ecological cascade, the intersection between climate and unsustainable fishing, conservation solutions, and much more. By the end of the course, students will have a deeper understanding of the challenges facing marine species and ecosystems, and they will possess data science skills that can be applied to future research.

Track 11 – Strategic Choices

The Power of Behavioral Economic Theory in Explaining Human (Mis)Behavior

Disciplines: Economics, Psychology, Game Theory, Behavioral Public Policy, Cognitive Science

Decision-making is part of everyday life, and it can have far-reaching impacts that set off a chain of events that cannot be predicted. For example, why do some students delay studying for a big exam, or why do some people avoid exercising? Researchers have combined economics and psychology to understand how humans act, what constitutes a good decision, and what makes a good decision-maker. In this course, students will examine how economists think people ought to behave through the lens of microeconomic and game theories. They will explore how cognitive and psychological biases may lead individuals to deviate from the normative economics framework and examine how conventional microeconomic theories have been extended to account for these behavioral anomalies to build more realistic models. Additionally, we will also look at areas of policies where insights about these cognitive biases have been fruitfully applied to improve people's decisions.

Track 12 – Neuromorphic Computing

Hardware and Software Co-design for Neuro-Inspired Engineering

Disciplines: Artificial Intelligence, Computer Engineering, Electrical Engineering, Information Theory, Neuroscience

The use of machine learning and artificial intelligence has exploded in recent years, with major advancements in performance driving a rapidly increasing demand. However, these advancements have failed to achieve general intelligence while incurring a significant cost related to increased compute and energy demands. In an attempt to combat these rising costs, researchers have drawn inspiration from the brain to push the field forward. This exploration has introduced innovations across the computing stack, from software algorithms to novel hardware and emerging materials. These techniques have allowed neural networks to solve many problems, from image recognition to natural language processing. This course will allow students to dive into techniques such as spiking neural networks and stochastic computing while exploring the mechanisms within the human brain that have inspired them. Using neuro-inspired computing, they will gain knowledge about the necessity of cross-stack collaboration in the current push for technological advancement.