IC Academic Research Symposium

6TH ANNUAL

INTELLIGENCE COMMUNITY ACADEMIC RESEARCH SYMPOSIUM

Program

WELCOME

John Beieler

Dr. John Beieler is the Director, Science and Technology within ODNI, a role he was selected for in June 2019. In this position, Dr. Beieler leads community efforts in science and technology as well as identifying opportunities for future activities to provide and maintain intelligence strategic advantage.

ODNI's Science and Technology Group is preparing the Intelligence Community to anticipate and face future mission challenges by informing and influencing the Community's science and technology investments through FY2025 and beyond.

Welcome to the sixth annual Intelligence Community Academic Research Symposium. This event was created in order to foster a strong and beneficial relationship between Academia and the Intelligence Community. The IC Academic Research Symposium is an opportunity for researches to broaden their knowledge of IC R&D interests, seek opportunities for collaboration on existing work, and develop new ideas and partnerships. By investing in the research that takes place in Academia, the IC has played an important role in the development of American scientists. It is the goal of the IC Academic Research Symposium to foster innovation and discovery while encouraging participants to learn, grow and embrace new perspectives.

About ICARS:

The Intelligence Community Academic Research Symposium is the showcase for unclassified academic research supported by the IC. This event provides the opportunity for academic researchers, advisors, and members of the IC to exchange ideas and engage with fellow experts from diverse scientific backgrounds. Through integration and cooperation, the IC Academic Research Symposium encourages innovation and collaboration between academia and the IC.

This year's participants and sponsors include:

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NGA Academic Research Program
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IC Academic Research Symposium

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Loren Alegria

Dr. Loren Alegria is interested in the materials science foundations of quantum technologies. Loren pursued his undergraduate studies under the advisorship of John Lipa and Aharon Kapitulnik at Stanford, developing precision measurements of low-temperature phase transitions in solids. In his graduate school he worked with Jason Petta at Princeton, studying applications of the newly-described topological insulator materials within the context of quantum electronics. He subsequently performed postdoctoral research at MIT with Jagadeesh Moodera, studying the quantum anomalous hall effect. As an IC Postdoctoral fellow, he works with Amir Yacoby at Harvard.

High-Energy Quasiparticle Injection in Mesoscopic Superconductors

At nonzero temperatures, superconductors contain excitations known as Bogoliubov quasiparticles. The mesoscopic dynamics of quasiparticles inform the design of quantum information processors, among other devices. Knowledge of these dynamics stems from experiments in which quasiparticles are injected in a controlled fashion at energies comparable to the superconducting energy gap. In this presentation, I will describe tunnel spectroscopy of a mesoscopic superconductor under high electric field. We study quasiparticle injection into titanium with 10^6 times the gap energy, an unexplored regime of quasiparticle dynamics. We expect that high-energy injection will be useful for developing quasiparticle-tolerant quantum information processors, will allow rapid control of resonator quality factors, and will enable the design of electric-field-controlled superconducting devices with new functionality.

Jerone Andrews

Dr Jerone T. A. Andrews is a Research Fellow in the Vision & Imaging Science Group at the Centre for Artificial Intelligence, University College London (UCL). He received an MSci (Hons) in Mathematics from King's College London in 2013, an MRes in Security Science from UCL in 2014, and a PhD in Computer Science from UCL in 2018 for a thesis titled: Representation learning for anomaly detection in computer vision. Jerone currently holds a Royal Academy of Engineering UK Intelligence Community Research Fellowship and is researching deep learning-based image forensics. In addition, he was recently awarded a British Science Association Media Fellowship. His research interests and expertise extend across computer vision and deep learning: from self-supervised anomaly detection, to human dimensional attention-inspired transfer learning, through to the use of generative adversarial networks for removing accidental device-linking 'watermarks' imprinted onto images by digital imaging sensors. While at UCL, Jerone has also spent time as a Visiting Researcher at the National Institute of Informatics (Tokyo, Japan) and Telefónica Research (Barcelona, Spain).

Conditional Adversarial Camera Model Anonymisation

Photographic images can be attributed to the specific camera model used for capture. Attribution is facilitated by inferring model-specific digital acquisition and processing artefacts present within high-frequency pixel patterns.

In this work, we are not concerned with attribution per se, but the challenging problem of camera model anonymisation. Model anonymisation is the process of transforming model-specific artefacts such that the apparent capture model is changed. Namely, the goal is to learn a function (represented by a neural network) that transforms the innate model-specific artefacts of an image to those of a disparate target model (e.g. Kodak M1063 to Ricoh GX100). Such a system could then be used for validating the robustness and reliability of attribution methods, particularly when the results are admitted as forensic evidence in court.

Previous works tend to view anonymisation as *solely* necessitating the attenuation or transformation of the device-specific pixel non-uniformity imaging sensor noise, which is defined as slight variations in the sensitivity of individual pixel sensors. Although initially device-specific, these variations propagate nonlinearly through the camera processing steps that result in the final image and thus end up also depending on model-specific aspects.

Pixel non-uniformity is the dominant noise component of photo-response non-uniformity. Photo-response non-uniformity noise, however, also contains contributions from low spatial frequency artefacts caused by a camera model's optics.

Model anonymisation approaches based on pixel non-uniformity invariably suppress the image content and instead work with the *noise residual* (the observed image minus its estimated image content). However, this precludes the anonymisation process from attending to low spatial frequency model-specific artefacts, since they no longer exist within the high-frequency noise residual. Differently, we cast model anonymisation as the process of transforming both high and low spatial frequency model-specific artefacts.

Through conditional adversarial training, we are able to learn targeted anonymising transformations which minimally distort images. Most notably, by decomposing images into their high and low spatial frequency components we constrain our system to *independently* reason over specific information present in each. This ensures that the learnt function transforms the full range of model-specific artefacts present within images. Quantitative results underscore the efficacy of our framework in settings where we have no *a priori* knowledge of the camera model attribution classifier used by a forensic examiner.

Charles Bachmann

Dr. Charles M. Bachmann received the A.B. degree in physics from Princeton University, Princeton, NJ, USA, in 1984, and the Sc.M. and Ph.D. degrees in physics from Brown University, Providence, RI, USA, in 1986 and 1990, respectively. From 1990 to 2013, he was a Research Physicist with the Naval Research Laboratory, serving first in the Radar Division from 1990-1997 and later the Remote Sensing Division from 1997-2013, where he was Head of the Coastal Science and Interpretation Section from 2003 to 2013. From 2012 to 2013, through the US Navy Engineer and Scientist Exchange Program, he was with the Defense Science Technology Organization, Maritime Division, Sydney, NSW, Australia. In 2013, he joined the faculty of the Rochester Institute of Technology Chester F. Carlson Center for Imaging Science (CIS) as the Frederick and Anna B. Wiedman Chair. Since 2016, he has been the CIS Graduate Program Coordinator. He holds two U.S. patents for methods of analysis related to hyperspectral remote sensing imagery. His research interests include hyperspectral and multi-sensor remote sensing of coastal and desert environments, BRDF and radiative transfer modeling for retrieval of geophysical and biophysical parameters, field calibration and validation, the development of advanced instrumentation (goniometers), as well as abstract models for interpreting hyperspectral and multi-sensor imagery based on manifold descriptions and graph theory.

Hyperspectral Video Imaging and Mapping of Littoral Conditions

Multi-temporal and multi-view remote sensing imagery offer significant benefits for mapping and modeling of littoral surface conditions. We have developed a low-rate hyperspectral video imaging capability that we currently use in our research related to the littoral environment. In more recent experiments, we have coordinated imagery collections from this mast-mounted system with simultaneous imaging from unmanned aerial systems (UAS) carrying a SWIR hyper-spectral imager and another carrying a multi-sensor payload with VNIR hyperspectral, LiDAR, broad-band thermal, and high-resolution RGB imaging systems. In the near future, a third UAS-based system, carrying a Ku-band SAR, will be added to the array of instrumentation. Our field research is complemented by laboratory-based hyperspectral goniometric measurements. These measurements provide highly detailed characterizations of the angular dependence of spectral surface characteristics. We use these measurements to develop and test physics-based radiative-transfer models for inverting geophysical surface parameters from imagery. We also deploy the hyperspectral goniometric system in field settings and operate it in tandem with our remote sensing imaging systems for calibration and validation of these models. Our research has been focusing on retrieval of key geophysical parameters among the set that most directly influence strength of the sediment and therefore trafficability: density, grain size distribution, roughness, moisture content, and composition (mixtures and layers). Through model inversion of hyperspectral multi-view and multi-temporal imaging modalities, we provide examples of retrievals of key geophysical parameters governing surface conditions and describe progress toward combining these retrievals into a single unified model describing these conditions. New thrusts within our research take advantage of the complementary imaging modalities available within our UAS payloads, including the LiDAR and stereo RGB imagery which can be used to provide digital elevation models, while future work will include thermal imagery and eventually SAR imagery.

Laurie Gaskins Baise

Professor and Chair
Tufts University

Prof. Laurie Baise teaches at Tufts University where she was promoted to Professor in 2015 and became Chair of the Department of Civil and Environmental Engineering in 2017. Prof. Baise received her B.S.E. from Princeton University from the Department of Civil Engineering and Operations Research with a certificate in Geological Engineering in 1995. She completed her graduate work at the University of California, Berkeley including a M.S. in both Civil and Environmental Engineering and Geology and Geophysics and a Ph.D. in Civil and Environmental Engineering in 2000. Prof. Baise's research spans the field of geotechnical earthquake engineering including liquefaction, site response, regional wave propagation, and ground motion prediction equations.

Benchmark Data Development to Classify Damage for Natural Disaster Relief Efforts

Prof. Laurie G. Baise, Prof. Babak Moaveni, Prof. Magaly Koch, Vahid Rashidian, and Lekan Sodeinde

In the aftermath of natural disasters, there is a need to assess damage across the impacted regions to inform stakeholders in estimating loss and planning response and recovery. The objective of this research is to improve the automated classification of multiple damage classes from overhead imagery to inform natural disaster response and recovery. In this first stage of the research, we propose to build and optimize a benchmark image library of damage features for testing and training automated supervised classification algorithms. Supervised classification requires benchmark training data and to date, the majority of benchmark datasets are event-specific. The proposed effort will build a benchmark image library of damage for use across events and available for future events. NGA's recent release of the xView dataset (Lam et al., 2018) which includes a collection of satellite images with multiple labels including "demolished building" and "intact building" is one such benchmark image library. Our own research in liquefaction evaluation (Zhu et al., 2017; Baise and Rashidian, 2018) has resulted in a temporal and geospatial database of liquefaction occurrence which if matched with imagery could be a parallel image library for liquefaction. Similar temporal and geospatial databases exist for other earthquake related damage (e.g. landslides: Nowicki et al. 2014; 2018). In the current effort, we are focused on evaluation of existing benchmark image libraries (buildings: xView and xbd), and creation of new benchmark image libraries (e.g. ground failures; lifeline infrastructure) optimized for training data for the supervised classification of building damage, infrastructure damage, and ground failure due to earthquakes across events.

In the first year of this project, we will be evaluating existing image libraries and developing new image libraries for ground failure and transportation infrastructure. Using the xView and xbd datasets for building damage, we are evaluating both segmentation and labeling for use with existing automated classification algorithms. Both datasets provide polygons to outline the buildings. Intact buldings are easily identified through standard segmentation algorithms. The challenge is in the classification. Image classification requires significant training datasets. We also evaluate several augmentation methods and their impact on accuracy statistics. This evaluation will inform how we segment and label new image catalogs. In this presentation, we will present our preliminary findings and lessons learned from these building damage image libraries.

In this presentation, we will present proposed methodologies for identification, mapping, and labeling for ground failure and transportation infrastructure. We will present our existing observation dataset and provide an outline of next steps toward building the image catalog. These methodologies draw on our domain experience.

Nathan Banek

Dr. Nathan Banek, is an IC Postdoctoral Fellow. He obtained his MS in Chemistry from The University of Toledo studying nanosized cubic zirconium tungstate, a negative thermal expansion material, in addition to in-situ non-ambient X-ray diffraction studies of indium tungstate. After publishing the discovery of a zirconium tungstate auto-hydration mechanism, he continued to research the material's hydration kinetics to determine the validity of its use in low-CTE polymer composites. Thereafter, he obtained his PhD in Chemistry from The George Washington University developing novel carbon nanomaterials from biomass for high-rate and low-temperature Li-ion cells, developed new synthetic methods to Si and Ge nanomaterials for Li-ion batteries, and designed a Li-ion cell for in-situ NMR analysis. His time at GWU resulted in four patent applications and ten publications. He received awards at the GWU Technology Commercialization Competition for best new technology two consecutive years, the 2018 American Institute of Chemists Student award, and the Bell Atlantic Graduate Fellowship. He will continue scientific research, this fall, at the Army Research Laboratory with the Sensors and Electron Devices division.

Sustainable Conversion of Biomass to Li-ion Grade Graphite

The present work as an IC Postdoc involves researching materials for high-energy density cells for satellites. The commercial Li-ion anode is predominantly graphite as it has high efficiency, long cycle life, and high operating potential. A largely overlooked problem with graphite is the production supply constraints that are anticipated to occur as the Li-ion battery market increases. With 70 % of graphite controlled by China, the US and EU have declared graphite a strategic and critical mineral. It makes up a $15 b industry with uses from Li-ion batteries, carbon raisers, conductive additives, carbon brushes, steel and aluminum refining. Battery grade graphite can be mined, but is deleterious to the environment, or created synthetically, a highly energy intensive process that creates harmful emissions. Obtained by either route, Li-ion battery grade graphite is expensive, $14,700 – 18,000 / ton. A new graphite production method is highly desirable, one that can be performed with domestic materials and at lower cost. Biomass can be inexpensive and is rich in carbon, oxygen, and hydrogen. When heated under inert atmosphere it breaks down evolving into liquid and gaseous fuels leaving behind a carbon rich product. Unfortunately, this carbon is non-graphitizable even at temperatures in excess of 3000°C. We have developed a new synthetic method that converts prevalent biomass and biomass components (sawdust, wood flour, lignin, cellulose, and corn stover) into high-purity, highly-crystalline graphite that is analogous to commercial Li-ion graphite. The graphite demonstrates excellent performance with high efficiency and minimal capacity loss over hundreds of cycles. The size, shape, and morphology of the graphite is controllable depending on the selected conditions. Moreover, the production rate of the graphite scales with energy input and required input energy (kWh/g of graphite) is significantly lower than synthetic graphite production methods.

Stephen Bass

Stephen Bass is a PhD candidate for Electrical Engineering at the Univeristy of Oklahoma. He recieved a bachelor's and master's degree in Electrical and Computer Engineering at the University of Oklahoma. He currently works as a Graduate Research Assistant at the Advanced Radar Research Center (ARRC) in Norman, Oklahoma under Dr. Jessica Ruyle. His research is focused in reconfigurable antenna design and advanced communication systems.

Electrically Reconfigurable Antennas

Most of his research has focused on frequency-agile and pattern reconfigurable antennas that are controlled by electronic means. Reconfigurable antennas have the ability to alter their radiating properties, allowing a fluid approach to bandwidth allocation, while more basic antenna systems with fixed bandwidths need allocated blocks of frequencies so that different systems can operate at their designed frequency without interfering with another source. The reconfigurable approach would have the antennas switch to an available frequency when it is needed instead of having certain frequencies restricted to certain systems even when not in use, allowing the available spectrum to be used more efficiently. Some reconfigurable antennas have been designed with mechanical switches or moving parts for reconfiguration. However the reconfiguration process for these systems can be slow and cause the parts to wear out, so efforts have been made to design reconfigurable antennas that can be switched electronically allowing for a smoother and faster reconfiguration. In addition to the operating frequency, another property that can be reconfigured is the radiation pattern of the antenna. A straightforward solution would be to physically move or rotate the antenna to shift where the primary radiating beam points. However, this method tends to be slow and the addition of motors and moving parts that can break down decreases its reliability. By electrically reconfiguring the radiation pattern instead, the antenna would reconfigure faster and be more durable over time. While one commonly-used solution is to place many antennas in a phased array configuration, his research has focused on creating reconfigurable elements that can expand their capabilities when placed in an array.

John Beck

John M. Beck, Ph.D. works as a Principal Research Scientist III for the University of Alabama in Huntsville's Information Technology and Systems Center. For the past twenty-five years, Dr. Beck has specialized in using geographic information systems (GIS) and remote sensing programs to solve real world problems. He currently conducts research in the areas of artificial intelligence/deep learning, remote sensing, and geospatial analysis. He holds a Bachelor of Science degree in Geology from the University of Alabama, a Master's of Science degree, and a Doctorate of Philosophy in Agronomy and Soil Science from Auburn University.

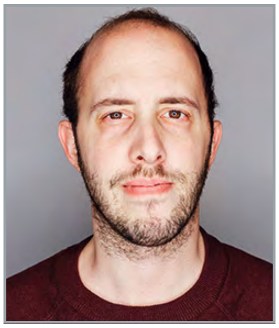
Prior to his employment with UAH, John served eight years as a Geospatial-Intelligence Analyst for the National Geospatial-Intelligence Agency's Support Team to DIA's Missile and Intelligence Center in Huntsville, Alabama. From 2005 to 2007, John was employed by the U.S. Fish and Wildlife Service as a Natural Resource Planner and from 1997 to 2005, John worked for Auburn University. From 1995 to 1997, he worked as a Remote Sensing /Geographic Information Systems Specialist with Lockheed-Martin and NASA's Commercial Remote Sensing Program located at Stennis Space Center, Mississippi.

Spatial Dynamics and Analysis of Crops Using Super Multispectral Image Resolution and Radar Fusion

As Earth's population escalates, global demand for food will increase at an alarming rate. Major challenges await global leaders in their efforts to secure stable and sufficient food supplies critical to the health and stability of their nations. Research efforts to support the spatial analysis (type, variety, growth, yield, and health) of agricultural crops and cropping patterns throughout the world are critical for understanding underlying factors and functional effects of the agricultural landscape. The ability to remotely perform these tasks quickly and efficiently will help NGA accurately monitor world food production, which is critical to the safety of our nation. Accurate up-to-date GEOINT on the incidence, nature and causes of chronic food insecurity and vulnerability allow policy makers to formulate ideas, implement policies, and design programs to mitigate world food shortages.

One technology that has been successfully used since the early 1970s to monitor world food production has been remotely sensed (RS) imagery. Now almost fifty years later, agronomists have many different RS sensors with increased spectral, spatial, and temporal resolutions available to assist. However, several challenges with RS imagery and crop analysis remain such as: the biophysical structures of most crops are similar and require extremely fine-resolution (< 0.5 m/pixel) multispectral imagery (MSI) for accurate identification, the mixing of spectral signatures within different crop types and within other types of vegetation, the amount of high variability in spectral signatures that occur during crop growth cycles and, the lack of optical RS sensor availability during weather events during key crop growth periods. To offset some of these issues, synthetic aperture radar (SAR) data has been successfully used to estimate soil moisture and plant heights. Although SAR data is extremely useful, researchers have found that combining information from multiple sources provides many advantages over a single RS sensor.

To address these challenges researchers at the University of Alabama in Huntsville's Information Technology and Information Center (UAH/ITSC) propose to extend their current research in **deep learning** and **super image resolution** to develop an improved method of pan-sharpening MSI and fusing the results with SAR data. Results will provide an enriched Geospatial Intelligence (GEOINT) product for conducting spatial analysis of agricultural crops. Once developed, we anticipate that this technology will be applicable to many other NGA domains such as foundational feature extraction and environmental monitoring applications. This technology will greatly impact NGA's mission by improving methods to use a wide variety of RS data together to solve complex problems.



Daniel Becker

Dr. Daniel Becker is a disease ecologist based at Indiana University. He completed his PhD in ecology at the University of Georgia, followed by a postdoctoral position at Montana State University focused on spatiotemporal infection dynamics and zoonotic pathogen spillover. Daniel is interested in how zoonotic pathogens spread within and between populations and species and how environmental change alters these infection dynamics. His Intelligence Community Postdoctoral Fellowship focuses on how migratory behavior and urbanization affects zoonotic disease, focused on dark-eyed juncos as a model system. Daniel will start as an Assistant Professor in the Department of Biology at the University of Oklahoma in Fall 2021.

Modeling Changes in Migratory Behavior as a Driver of Zoonotic Disease in an Avian Host

Most zoonotic pathogens originate from wild species, many of which undertake long-distance migrations between their breeding and wintering grounds. Understanding how migratory behavior affects infection dynamics in wildlife is especially important in the context of environmental change, as many naturally migratory species are using urban habitats as stopover sites or as their wintering grounds and even abandoning migration in favor of forming sedentary populations in cities. These changes in migratory behavior are especially common in birds, many of which are reservoirs of zoonotic pathogens. Here, I present results from three complementary approaches to modeling the impacts of migration on infectious disease risks in avian systems. First, I used boosted regression trees to assess the role of migratory behavior in shaping whether bird species can transmit *Borrelia burgdorferi*, which causes Lyme disease, to ticks. This model characterized competent reservoirs with 76% accuracy and found that birds with more diverse migratory movements into their breeding grounds are more likely to transmit to ticks. Alongside predicting birds that may play important roles in the global epidemiology of Lyme disease, this model also suggested long-distance movement itself could affect the ability of birds to replicate and transmit pathogens. Migrations are energetically expensive, and impaired immunity from preparing for long-distance movements can cause latent infections to reactivate. To explore the population-level consequences of "migratory relapse", I next built a susceptible–infected–latent–infected model with ordinary differential equations. This model demonstrated that relapse upon departure can dramatically increase infection prevalence and allow hosts to arrive at the breeding grounds primed to infect new hosts or vectors. Such results suggest that monitoring migratory animals at stopover sites or upon summer and winter arrival may improve pathogen surveillance, and I am now screening samples from birds prior to and after spring and fall migrations to test these predictions. However, this model also showed that reactivation can decrease disease risk when infection carries high costs to survival, as recently relapsed hosts are rapidly culled from the population with migration. Lastly, as many migratory species overwinter in urban regions, these habitats could affect the probability of relapse upon spring departure. I used an experiment to test how artificial light at night, a pervasive aspect of urban habitats, affects pathogen intensity across the annual cycle of migratory and resident birds. Using generalized additive models, I showed that artificial light at night amplified pathogen intensity in the spring and fall and was driven by dysregulation of the host immune system. Collectively, these models provide key insights into how migratory behavior affects zoonotic pathogen dynamics in wild animals.

David Benirschke

Dr. David Benirschke received his BSEE from the electrical engineering department at Purdue University Northwest. While an undergraduate, David participated in the Fermilab Summer Internships in Science and Technology (SIST) program where he worked on detector design for the muon to electron conversion experiment (Mu2e). From 2014 until 2020, David was a Dean's Fellow at the University of Notre Dame where he pursued his Ph.D. His Ph.D. research focused on implementing a low size, weight, power, and cost hyperspectral, mid-infrared imaging system for explosives detection. This research was sponsored by the Awareness and Localization of Explosives Related Threats (ALERT) center of excellence within homeland security. This collaboration granted him the unique opportunity to interface with government, academic, and industrial partners and has driven his interest in designing field-deployable systems and transitioning equipment from the lab bench to the real world.

Currently, David is an IC postdoctoral scholar at the University of Notre Dame working with Professor David Burghoff and Dr. Dana Berkelend. His current research is on the implementation of a frequency comb based hyperspectral imaging system.

Frequency Comb Based Hyperspectral Imaging Systems

Mid-infrared spectroscopy for the characterization and identification of substances has proven to be an invaluable tool in today's modern laboratories. As an optical technique, mid-infrared spectroscopy allows for non-destructive, long-distance interrogation of objects. These benefits have been leveraged to realize a plethora of detection applications including pipeline gas leak monitoring, explosives detection systems, and inline process monitoring at factories. However, these techniques have yet to find widespread usage as they have remained prohibitively large, heavy, power-hungry, and expensive. Also, these systems often require moving parts and access to liquid nitrogen making portability an issue. To allow for field-deployable systems a paradigm shift in the generation and detection of mid-infrared light is required. Such a paradigm shift may be realized by utilizing quantum cascade laser-based frequency combs. Frequency combs are novel broadband light sources consisting of perfectly evenly spaced spectral lines. While created for optical metrology, combs very quickly found use in optical spectroscopy as they allow for researchers to measure high sensitivity data with broad bandwidths. Thus, combining the benefits of multiplexed spectroscopies, such as FTIR, with that of laser spectroscopies onto a single platform. Additionally, these systems function entirely without moving parts and can be made chip-scale.

In this work, the development of a mid-infrared, frequency comb based hyperspectral imaging system is presented. This system is based on pulsed, chip-scale quantum cascade lasers allowing for the potential of low size, weight, and power applications. In addition, a new high-resolution comb based measurement technique is demonstrated. This technique, which the authors refer to as frequency ptychoscopy, allows one to reconstruct the spectrum of any arbitrary light source utilizing combs. This is in contrast to previous multiheterodyne comb techniques which could only measure coherent sources such as lasers. The key idea behind ptychoscopy is a piece-wise reconstruction of the spectrum by reuse of a narrow bandwidth. This solves the bandwidth limitation of other multiheterodyne techniques and allows for the measurement of spectrum spanning multiple comb lines. Finally, future work is proposed on expanding this comb-based spectroscopy system into a full-fledged hyperspectral imager.

Andrea Bertozzi

Dr. Bertozzi is an applied mathematician with expertise in nonlinear partial differential equations, geometric methods for image processing, crime modeling and analysis, and swarming/cooperative dynamics. Bertozzi completed all her degrees in Mathematics at Princeton. She was an L. E. Dickson Instructor and NSF Postdoctoral Fellow at the University of Chicago from 1991-1995. She was the Maria Geoppert-Mayer Distinguished Scholar at Argonne National Laboratory from 1995-6. She was on the faculty at Duke University from 1995-2004. Bertozzi moved to UCLA in 2003 as a Professor of Mathematics. Since 2005 she has served as Director of Applied Mathematics. In 2012 she was appointed the Betsy Wood Knapp Chair for Innovation and Creativity. Bertozzi's honors include the Sloan Research Fellowship in 1995, the Presidential Early Career Award for Scientists and Engineers in 1996, and SIAM's Kovalevsky Prize in 2009. She was elected to the American Academy of Arts and Sciences in 2010 and to the Fellows of the Society of Industrial and Applied Mathematics (SIAM) in 2010. She became a Fellow of the American Mathematical Society in 2013 and a Fellow of the American Physical Society in 2016. She won a SIAM outstanding paper prize in 2014 with Arjuna Flenner, for her work on geometric graph-based algorithms for machine learning. Bertozzi is a Thomson- Reuters/Clarivate Analytics `highly cited' Researcher in mathematics for both 2015 and 2016, one of about 100 worldwide in her field. She was awarded a Simons Math + X Investigator Award in 2017. In May In 2018 Bertozzi was elected to the US National Academy of Sciences; In 2019 she was awarded SIAM's Kleinman Prize.

Sparsity Models for Spatiotemporal Analysis and Modeling of Human Activity and Social Networks in a Geographic Context

This presentation includes Christian Parkinson and Bohan Chen – two PhD students who have been involved in the research.

We will review two recent works on optimal path planning. (1) We address the problem of optimal path planning for a simple nonholonomic vehicle in the presence of obstacles. Most current approaches are either split hierarchically into global path planning and local collision avoidance, or neglect some of the ambient geometry by assuming the car is a point mass. We present a Hamilton-Jacobi formulation of the problem that resolves time-optimal paths and considers the geometry of the vehicle. (2) We address the problem of practical patrol strategies for environmental crime, in which the patrol density is considered as an important parameter.

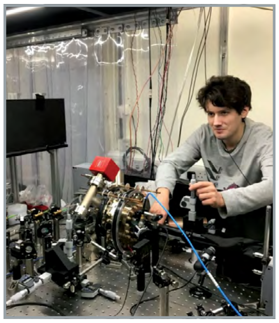
However, in actual situations, not all patrol strategies are realistic. This work defines a practical patrol strategy in terms of ways to send each group, the path each patrol group takes and the time arrangement of each group. We discuss methods that generate a patrol density function based on practical strategies and that find the nearest practical strategy to a certain patrol density.

Eduardo Blanco

Dr. Eduardo Blanco is an Associate Professor in the Department of Computer Science and Engineering at University of North Texas. He conducts research in natural language processing with a focus on computational semantics, semantic relation extraction and inference, and intricate linguistic phenomena such as negation, modality and uncertainty. His work is supported by the National Science Foundation, the National Geospatial-Intelligence Agency, the Patient-Centered Outcomes Research Institute, and generous gifts from industry. Blanco is a recent recipient of the Bloomberg Data Science Research Grant and the National Science Foundation CAREER Award.

Mining Spatiotemporal Knowledge from Language and Images

People communicate in social media using both language and images. In this talk, we will present ongoing work aimed at mining spatiotemporal knowledge using information extracted from the text and images in social media posts. We show that people are often not located in the places they mention in their posts. We also show that the text and images complement each other, that is, that coupling the cues provided in the text and images yields richer and less ambiguous spatiotemporal inferences. For example, a picture of a U-Haul truck indicates that somebody is moving to a new place even if the text does not mention it. We will close with preliminary results, and our plans to build a large resource and computational models to solve this problem.



Harry Bostock

Dr. Harry Bostock is UK IC Postdoctoral Fellow at the University of Sussex studying how to exploit trapped Ytterbium ions for quantum sensing for RF and microwave detection. His area of interest is quantum sensing and ion trapping with Paul trap, as well as experience with Nuclear physics and anti-matter trapping.

Dr. Bostock studied physics at an undergraduate level at The University of Swansea, where he completed a fascinating project on efficient methods of compressing electron plasma to assist with the trapping of anti – hydrogen using Penning traps.

Developing a Trapped Ion Quantum RF and Microwave Sensor

RADAR and RF detection are traditionally the realms of classical detectors, such as microwave dishes and RF antennas. A problem with these techniques however is that they are very susceptible to noise due to their inherent high bandwidth reducing their signal to noise ratio.

We are working on developing a quantum solution to this problem, using Ytterbium ions trapped on microfabricated 2-D Paul traps. This technique will potentially provide far greater sensitivities and the ability of narrower bandwidth detection than traditional classical devices. This platform is also superior to other quantum sensors, which generally work at DC or very low RF (~Hz), while our sensor should be effective at high RF (1 MHz – 150 MHz) and even 12.6 GHz (± 100 MHz) microwaves.

We have already been successful in constructing a fully functioning quantum sensor, which has demonstrated both RF and in a world first: microwave sensing. This system consists of a vacuum system that contains a microchip capable of trapping ion in an ultra-high vacuum environment. The ion can then manipulated to become incredibly sensitive to a tuned RF and microwave frequency by changing the magnetic field.

We have used this system to demonstrate RF and microwave sensitivities in the region of ~100 pT/sqrt(Hz), which is the lowest sensitivity accomplished for microwaves using a quantum sensor! This sensor has also demonstrated an ability to determine the frequency of a signal down to the ~Hz level, although we hope to go lower in the future.

So what problems in the real world can this quantum sensor solve? Well you may have heard that there is a lot of demand for detecting drones and critically, determining their location. This can be resolved by using our sensors high sensitivity coupled with its noise avoiding ability, would give a high signal-to-noise ratio, so a drones position and heading could be determined quickly even in a noisy environment such as an airport.

In addition, our technology opens up the possibility of better radar systems! The high sensitivity and low bandwidth would not only increase the range of a RADAR station, but also be able to determine the speed and heading of an aircraft within ~1ms^{-1}.

The detection of explosives and narcotics using the nuclear quadrupole resonance (NQR) technique has so far been rather limited using classical techniques. Our sensor opens up the possibility of detecting explosives at range using NQR, due to its ability to pick out very weak signals in noisy environments.

We are currently focused applying our sensor to the task of detecting surreptitious listening devices using enhanced quantum sensing techniques. We also develop more advanced ion microchips for this application, such as the advanced dual-rail design developed by our microfabrication team. This should allow us to sense with far greater sensitivity and be able to conduct RF and microwave field measurements in under a second!

Christine Brugh

Dr. Christine Brugh is a technical program manager with the Laboratory for Analytic Sciences at North Carolina State University, where she works on projects related to Influence and Analytic Rigor. Dr. Brugh completed her doctoral studies in psychology at North Carolina State University; her dissertation research used rigorous methods to examine subpopulations of terrorism involved individuals, which identified likely correlates of terrorism involvement. She has published work on the characteristics of women involved in jihadism-inspired terrorism and the prevalence of risk indicators among lone actor terrorists. Dr. Brugh is currently involved in projects on state-level correlates of terrorism, differences in roles within terrorist organizations, and finding risk factors for engagement in violent extremism. Her research interests include drivers of women's involvement in terrorism and prison radicalization.

The Heterogeneity of Terrorist Actors and Outcomes

Increasingly behavioral assessment professionals, such as psychologists, are asked to support efforts to counter violent extremism, including assessment of risk. Though hundreds of papers have been written on why people engage in violent extremism (Desmarais et al., 2017), this work is limited in several ways that preclude establishment of risk factors for violent extremism which are based on statistical evidence. In particular, the literature is predominantly theoretical, with heavy reliance on case studies that may not generalize across cohorts, extremist organizations, or over time. Extant research has lacked specificity regarding both the individuals and outcomes of interest (e.g., terrorist types, roles, organizations, attack type), as well as other key constructs, including ideology. The problem of establishing risk factors is further complicated by the lack of research utilizing non-extremist comparison groups. Though it may be interesting to note, for example, the prevalence of diagnoses of mental illnesses among individuals with violent extremist ideology, this finding does not mean much for the assessment of risk without (1) a comparison to rates of mental illness among similar individuals in the non-extremist general population, and (2) definitive evidence that the factor precedes the outcome of interest (Craemer et al., 1997).

This presentation will review recent work from two projects addressing research questions within the theme of heterogeneity of terrorist actors and outcomes. In the first project, we examine the relationship between individual and state-level characteristics, finding that different associations between these are predictive of different terrorism outcomes, such as domestic versus foreign plot involvement. In the second project, we explore differences in types of extremist action, such as planned mass casualty attacks versus spontaneous interpersonal violence, as well as the characteristics of individuals who engage in each type of action. Finally, this presentation will outline ongoing efforts to develop matched comparison groups of extremists and non-extremists with the goal of establishing risk factors for violent extremism.

Nathan Carter

Dr. Nathan A. Carter is an Intelligence Community Postdoctoral Fellow in in the Mechanical Engineering Department at the University of Minnesota. He received his Ph.D. in Chemistry from Virginia Tech in 2017 under the guidance of Prof. Tijana Grove. His research interests lie in integrating electronic systems at the bio-synthetic interface. With recent advances in brain-machine interface systems and controls, material development that prioritizes substrate compatibility between electronics and biomaterials is becoming ever more important. While not directly applied to biological systems in its current form, his research focuses in two complimentary directions toward developing biocompatible integrated electronics: 1) designing low-temperature sintering metallic inks suitable for direct-write 3D printing and 2) designing printable substrates comprising bio-compatible polymers which have good substrate adhesion and impart self-healing properties to increase device lifetimes.

Development and Direct-Write Printing of Low-temperature Sintering Inks on Flexible and Self-healing Substrates

3D-printing provides a compelling alternative manufacturing strategy to traditional microfabrication for certain devices in that it is capable of single-process direct-writing of electronic elements into fully integrated devices. Promising applications include tissue engineering scaffolds and materials, soft actuators, deployable smart medical devices, and other flexible electronics. These applications will benefit from adaptability to print on arbitrary, curved substrates, which are not generally accessible to microfabrication strategies. To properly take advantage of these benefits, printable inks must be formulated to: 1) exhibit good adhesion to a variety of chemically different surfaces, 2) have tunable mechanical properties to ensure printability as well as match the mechanical properties of the substrate and 3) enable low temperature processability to maximize substrate compatibility.

To address these areas, this research focuses on two complimentary directions 1) development of rapid, low-temperature sintering metallic inks for interconnect printing and 2) exploring the structure-property relationships of self-healing and dynamic catechol-containing polymers. Catechol incorporation is inspired by mussel-adhesion proteins and is of particular interest because of these materials have been shown to have broad substrate compatibility and adhesion, are biocompatible and also impart self-healing properties all of which may help promote device longevity.

Janna Caspersen

Janna Caspersen Ph.D. is an Oak Ridge Institute Science and Education (ORISE) Visiting Scientist at the National Geospatial-Intelligence Agency. Her research currently focuses on qualitative narrative analysis of social media using machine learning. Her doctoral work at the University of Tennessee focused on the geographies of social media, mixed methods, qualitative geographic information sciences, and critical race theory. While completing her Ph.D., she worked at Oak Ridge National Laboratory (ORNL) for the Geographic Information Science & Technology Group assisting with population density research. Previously, Dr. Caspersen conducted her Master's research by locating Sudanese ethnic groups using subject matter experts and participatory research methods at East Carolina University. She has also assisted on a wide variety of research and development initiatives. These included: locating and mapping MLK Streets for the National Civil Rights Museum, sustainable tourism data gathering in Cuba, suitable habitat modeling in Honduras, and multicultural competence development through experiential and place-based learning.

Candace Chan

Dr. Candace K. Chan is an Associate Professor of Materials Science and Engineering at Arizona State University (ASU). She received a B.S. in chemistry from Rice University in 2005, where she worked in the lab of Nobel Laureate Prof. Richard Smalley, and Ph.D. from Stanford University in 2009, where she was the first Ph.D. student of Prof. Yi Cui. After postdoctoral research at UC Berkeley as a Miller Fellow, Dr. Chan joined the faculty at ASU in 2011 as an Assistant Professor in the School for Engineering of Matter, Transport and Energy and Graduate Faculty in the Department of Chemistry & Biochemistry (now the School of Molecular Sciences). She was awarded the ASU Young Investigator Award in 2014 and was promoted to Associate Professor and named a Fulton Exemplar Faculty in 2017. She was a visiting guest professor at the Max-Planck-Institute für Kohlenforschung from 2016 – 2019 with support from an Alexander von Humboldt Research Fellowship. Her research group at ASU is currently working on critical materials issues mostly in the fields of lithium batteries/energy storage, but with additional efforts in photocatalysis and water treatment using engineered nanomaterials. Notable battery research highlights include the demonstration of foldable lithium-ion batteries, the development of nanostructured solid electrolyte materials for all-solid-state lithium batteries (through an NSF CAREER award), and investigation of novel clathrate based materials for electrodes.

Integrated Foldable Battery and Components with Flexible/ Stretchable Interconnects

Candace K. Chan
Arizona State University

The need for robust battery technologies for portable electronics has been apparent for several decades and is becoming more important as power demands inevitably increase while physical attributes such as mechanical flexibility become more desired. Arizona State University (ASU) has developed a methodology for the fabrication of foldable power technologies by applying origami, the art of paper folding, to impart compactness and 3D morphologies to lithium-ion batteries. The use of paper as substrates for Li-ion battery electrodes not only creates a natural opportunity to exploit paper-based batteries to achieve energy storage devices with improved areal energy density, smaller footprints, and adaptable form factors with extreme configurability and flexibility, but also provides for new opportunities for seamless integration with other flexible electronic devices. ASU has also developed different types of stretchable interconnects utilizing various geometrical designs to enable extreme stretchability in materials that conventionally lack deformability. Compact interconnects consisting of novel polymer composite materials also provide excellent electrical conductivity, stretchability, and flexibility even at large deformations.

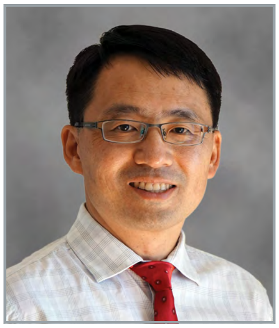
This research program aims to address the aforementioned challenges and knowledge gaps with an interdisciplinary and collaborative approach that builds upon the expertise and experience of ASU professors *Candace K. Chan*, *Hanqing Jiang*, and *Hongbin Yu*. Through three research thrusts focused on (1) *Foldable battery development*; (2) *Interconnects development*; and (3) *Packaging and Systems development*, the project aims to assess failure modes and develop engineering solutions to realize highly deformable integrated systems comprising foldable electronic devices powered by high energy density and long cycle life batteries. Herein, preliminary results on the properties of paper-based battery current collectors, stretchable polymer composite interconnects, and deformation behavior of electrode laminates under various degrees of flexing and bending will be presented.

Expanded Temperature Range Li-Ion Battery Electrolytes Using Eutectic Mixtures

Candace K. Chan
Arizona State University

The high energy density and power characteristics of Li-ion batteries have made them the energy storage technology of choice for an increasingly large number of applications. A major limitation, however, is the inability of Li-ion batteries to be used over a wide range of temperatures, mostly due to issues originating from the electrolyte. At low temperatures, changes in electrolyte viscosity, crystallization status (*i.e.,* freezing), and ionic conductivity can lead to dramatic decreases in battery performance. At high temperatures, thermal degradation of electrolyte salts and/or solvents, along with deleterious side reactions with electrode materials can lead to higher battery impedance and capacity loss. To date, there is not yet a single electrolyte system that enables satisfactory capacity and power delivery over the temperature range of – 20 to +60 °C. Three major challenges are finding electrolyte components that will 1) remain liquid at low temperatures, while 2) displaying low viscosity, high ionic conductivity, good (electro)chemical stability with other components of the battery, and 3) retain the ability to form electronically passivating yet ionically conducting solid electrolyte interfaces (SEI) on the negative electrode in the above-mentioned temperature range.

In this project led by Candace K. Chan and C. Austen Angell, Arizona State University (ASU) leverages previous experience in battery research to develop new electrolytes that will enable Li-ion battery performance at extreme temperatures that is comparable to that at room temperature. To address the challenges of wide-temperature range electrolytes, this project investigates sulfone molecules as the key ion solvating component for new electrolytes that will display suitably low viscosity, high ionic conductivity, and good chemical stability at temperature extremes. While sulfone molecules have good oxidative stability, electrolytes comprising sulfones as solvents typically suffer from high viscosity and the inability to create SEI passivation layers on graphite anodes. Therefore, this project seeks to develop eutectic mixtures of sulfones with viscosity-lowering co-solvents, thermally stable salts, SEI-film forming additives, and separator wetting agents as key strategies towards the development of new electrolytes that will be effective at extreme temperatures. Herein, our preliminary results on the membrane wettability, thermal characteristics, ionic conductivity, and electrochemical compatibility of sulfone-based electrolytes will be presented.



Jorge Chen

Dr. Jorge Chen is a research scientist at the Oak Ridge Institute for Science and Education (ORISE). His research centers on indoor cartography, indoor mapping, and mobile mapping, with an emphasis on multi-sensor fusion and accuracy assessments. His recent research topics include the fusion of 3D geometry from omni-directional images with laser scans; spatio-temporal accuracy analysis of 3D remotely sensed data; and the collaborative hardware and software design of mobile scanning systems. He is a retired lieutenant colonel in the Air Force Reserve and has served as a civil engineer on two combat tours as well as several other overseas deployments.

Mobile Indoor Laser Scanning Using COTS and Open Source

Indoor space remains a relative enigma in mapping science, especially when it comes to the third dimension. Historically, this has been largely due to the scarcity of remotely sensed indoor data and the absence of practical computational systems. Recent advancements in areas such as miniaturized 3D scanners and deep learning have removed those barriers, making it possible to create these 3D indoor maps. However, technical feasibility does not automatically imply operational effectiveness. Creation of this new breed of maps requires a re-thinking of cartography in terms of both theory and technical practice. This presentation looks at one part of the technical practice: a human-portable indoor mobile laser scanning system that uses low-cost commercial off-the-shelf hardware and open source software. Topics covered include a discussion of the hardware components (e.g., Ouster scanners, nine-axis inertial measurement unit, single board computers, etc.), open source software components, human factors design considerations, graphical user interface design, and a demonstration of an open source simultaneous localization and mapping (SLAM) algorithm applied to this system. As part of a larger modular system, this system can be quickly reconfigured for outdoor scanning on a number of alternative carrier platforms.

John Chivers

Dr. John Chivers has a B.S. in Physics from the University of Massachusetts at Amherst and a Ph.D. in Electrical Engineering from Tufts University. His research focuses on materials and devices for use in infrared energy harvesting. Current projects include selective emitters for infrared wavelengths, high speed diodes, nano-scale antennas, and Si/Ge/Sn molecular beam epitaxy. All research projects are focused on application to infrared energy harvesting.

An Integrated System for Thermophotovoltaic Power Generation

We are developing a solid-state power generation system to harvest infrared light. Thermophotovoltaic (TPV) cells can directly convert radiated thermal energy into electric power, through a process similar to how traditional photovoltaics work. Alternately, wavelength-scale rectennas can perform the same function by coupling to and rectifying the incident EM field. Practical power generators must also include additional system components. These components, selective-emitters and filters, shape the way the radiated heat is transferred into the TPV cell for conversion and are critical for efficiency. We are designing a complete system to include all needed components in a single, robust package. This device will allow electricity to be produced from nearly any thermal source for both primary power generation and waste heat harvesting.

Gordon Christie

Dr. Gordon Christie is a senior researcher at The Johns Hopkins University Applied Physics Laboratory, where he has worked since the beginning of 2017. He received his B.S. in Computer Engineering from West Virginia University in 2011, and his M.S. and Ph.D. degrees in Computer Engineering from Virginia Tech in 2013 and 2016, respectively. During his graduate studies, he also spent some time at the Army Research Laboratory as a visiting researcher working on problems related to localizing unmanned systems in GPS-denied environments. Gordon has been involved in a diverse set of research projects at JHU/APL involving computer vision, machine learning, remote sensing, and robotic systems.

Semantic Representations for Multi-Viewpoint Multimodal Geolocation

Our work will address some of the key challenges for geolocalization and 3D mapping from multimodal data captured by unmanned aircraft systems (UAS). As US government agencies collect more data, it becomes increasingly difficult for analysts to keep up. Requiring analysts to reason across multiple modalities of data and viewpoints adds a lot of complexity to this task, resulting in significantly slower analysis or analysts skipping data entirely. Our research will develop and evaluate methods to automate the aggregation of multimodal data, enabling analysts to more easily access and analyze relevant data for an operation. We are also focused on improving UAS geolocalization by leveraging recent advances in deep learning to develop algorithms capable of learning common, cross-modal, and semantic representations between UAS sensor data and base maps to take full advantage of all available data sources.

Team: Dr. Nathan Jacobs (University of Kentucky), Ryan Mukherjee (JHU/APL)

Robert Colter

SMSgt Rob Colter is an Air Force All-Source Intelligence Analyst with 22 years in the service. Previously the Intelligence Surveillance and Reconnaissance Division Superintendent for the 607th Air Operations Center at Osan AB, Korea, he spent the last year completing a Masters of Science and Technology Intelligence at the National Intelligence University Campus in Bethesda Maryland. There he completed his research into the country specific influence nodes and influence transactional behaviors as his Graduate Thesis. He is currently transitioning to a position at the Defense Intelligence Agency.

Identifying Influence Behaviors Among Nationally Sorted GitHub User Populations

Despite a wealth of research into the social coding site GitHub, little work has been done to characterize the differences, if any, between populations of users on the platform with differing national backgrounds, as almost every study has either focused on the whole user/repository population or a small randomly selected slice. However, what research does exist demonstrates clear paths and techniques that might be used characterize different populations of GitHub users. This study aims to explore this gap in knowledge on the subject. Asking, do differing nation sets of users on GitHub exhibit unique influence node sets and behaviors? In this context, influence nodes are those users and their code repositories on the platform who have gained influence through the preferences of other users, and influence behaviors are the transactions between users that lead to that influence gain.

Based on a review of the literature covering previous study into the subject, a proxy database containing transactional data for GitHub users covering the period from GitHub's inception in April 2008 until June 2019 was obtained, and methods where developed to assess influence transactional behaviors and identify user and repository influence nodes. Four nations were selected for study (Russian, China, the United States, and India) and their user populations and transactions were isolated from the database. Analysis of these users found that in all three areas studied, influence transactional behaviors, user influence node types, and repository influence node types, there was significant variance between the populations. The results indicate that yes, there are significant differences between the influence behaviors and nodes of differing nations. These results also lend themselves to further research into the behaviors of smaller subsets of these populations and have possible implications for assessing the technical abilities of different nations and groups utilizing the GitHub platform.

Ryan Corey

Dr. Ryan M. Corey is an Intelligence Community Postdoctoral Research Fellow working with Professor Andrew Singer in the Coordinated Science Laboratory at the University of Illinois at Urbana-Champaign. He received the B.S.E. degree from Princeton University and the M.S. and Ph.D. degrees from the University of Illinois at Urbana-Champaign, all in electrical engineering. A hearing aid user since he was a teenager, Dr. Corey's research focuses on signal processing strategies to help people hear better in noisy environments. Since 2017, he has mentored a team of engineering, design, and business students in the Illinois Augmented Listening Laboratory, which explores applications of large-scale microphone arrays and acoustic sensor networks. Dr. Corey has received the National Science Foundation Graduate Research Fellowship, the Microsoft Research Dissertation Grant, the Microsoft AI for Accessibility Award, and the Intelligence Community Postdoctoral Research Fellowship. He was also awarded the WASPAA 2019 Best Student Paper Award for the paper entitled "Motion-Tolerant Beamforming with Deformable Microphone Arrays."

Cooperative Listening with Networked Audio Devices

It is often difficult to hear in noisy environments with many competing sound sources. Fortunately, rooms with large crowds of people also have large numbers of microphones. Tiny embedded microphones are found in mobile phones, wearable accessories, computers, voice-activated gadgets, and conferencing systems, among many other devices. If these microphones could be connected together, they could help humans and machines to listen more effectively in challenging environments. It is difficult to aggregate signals from asynchronous devices over networks that may have poor bandwidth, latency, and reliability, especially for real-time applications like human listening enhancement. This work demonstrates a cooperative processing approach in which individual devices perform real-time signal processing locally but leverage data and computational resources from the distributed network to analyze the acoustic environment and achieve better performance than they could alone.

Jordan Crouser

Dr. R. Jordan Crouser is an Assistant Professor of Computer Science at Smith College, a visual analytics researcher and semi-professional data wrangler. His research program investigates the complementary nature of human and machine computation as used in visual analytics and other human-machine collaborative systems. These systems make use of the human visual system, as well as our capacity to understand and reason about complex data. He has published his technical contributions in the areas of visualization theory, human-computer interaction, educational technology, visual analytics systems and human computation. Prior to returning to academia, Crouser spent two years doing research and building analytical tools at MIT Lincoln Laboratory.

The Role of Individual Differences in Moderating Complex Analytic Workflows

Developments in data visualization research have enabled visualization systems to achieve great general usability and application across a variety of domains. These advancements have improved not only people's understanding of data, but also the general understanding of people themselves, and how they interact with visualization systems. In particular, researchers have gradually come to recognize the deficiency of having one-size-fits-all visualization interfaces, and have shown that the effectiveness of a visualization tool depends on the experience, personality, and cognitive abilities of the user. This work has also demonstrated that these individual traits can have significant implications for tools that support reasoning and decision-making with data. However, most studies in this area to date have involved only short-duration tasks performed by lay users. In this talk, we will review the research perspectives, as well as the personality traits and cognitive abilities, visualizations, tasks, and measures investigated in the existing literature. We will then present a preliminary analysis of a series of exercises with 22 trained intelligence analysts that seeks to deepen our understanding of how individual differences modulate expert behavior in complex analysis tasks.

Curt Davis

Dr. Curt H. Davis received the B.S. and Ph.D. degrees in Electrical Engineering from the University of Kansas in 1988 and 1992, respectively. He is currently the *Naka Endowed Professor* of Electrical Engineering & Computer Science at the University of Missouri (Columbia, MO) and *Director of the Center for Geospatial Intelligence* which he founded in 2005. Over his 30-year scientific career his research has involved the use of satellite remote sensing systems for numerous applications in the areas of earth observation and science including ice sheet monitoring, change detection, geospatial information processing, and national security. His current research is focused on the development and application of deep machine learning methods for object detection and scene recognition to improve analytic workflows involving the search, discovery, retrieval, and/or monitoring of objects and features of interest in large volumes of high-resolution satellite imagery. His research results have been documented in more than 60 refereed journal publications and 90 symposia presentations and proceedings. His most significant scientific studies have been published in top scientific journals like *Science* and *Nature* while the majority of his technical contributions to the field of remote sensing have been published various IEEE journals. In 2008, Dr. Davis was named an IEEE Fellow for his "contributions to satellite remote sensing" and has received numerous other awards throughout his career.

DeePRK - Measuring Human Performance of DNN-Assisted Object Search and Detection over North Korea

Within the last five years, Deep Neural Networks (DNN) have shown through extensive experimental validation to deliver outstanding performance for object detection/recognition in a variety of benchmark high-resolution remote sensing image datasets. The demonstrated ability of DNNs to automatically detect a wide variety of man-made objects with very high accuracy has tremendous potential to assist human analysts in labor intensive visual searches for objects of interest in high-resolution imagery over large areas of the Earth's surface. However, the vast majority of published studies for DNN object detection in remote sensing imagery have focused on development of new deep learning algorithms/methods and/or comparative testing/evaluation of these methods on benchmark datasets (both public and private). Consequently, only a small number of studies have attempted to apply promising DNN methods to demonstrate efficacy via applications to large-scale or broad area remote sensing image datasets.

In this research, we have developed a human-machine teaming framework, DeePRK, for large-scale application of advanced DNN to commercial high-resolution satellite EO/MS image data over the country of North Korea (DPRK). A fully-automated high-performance image processing pipeline is used to generate "tipping and cueing" DNN detection results for subsequent review by human imagery analysts. A custom web user interface is used by image analysts to perform rapid serial review of rank-ordered (using aggregated confidence) DNN detection results over a given search area.

In this first year's effort we are training ~20 different DNN to detect a wide variety of relevant feature/object classes from both military and foundation GEOINT thematic groups. The feature/object classes were selected with input from several NGA analytic branches. Traditional human visual searches (unassisted) are first performed for each feature/object class to establish a baseline set of human performance metrics. Then, the DNN-assisted searches are conducted over the same search areas using the same commercial EO imagery. The results from both the traditional and DNN-assisted image analyst reviews over various search areas are stored in a database. A variety of metrics (*F1*, precision, recall, search rate, etc.) are then computed to quantitatively assess human performance metrics for both the traditional and DNN-assisted object search and detection. The visual and DNN-assisted searches are in progress for all ~20 feature/object class and initial results from the first-year's experiments will be presented in this talk.

Kevin Dobbs

Dr. Kevin Dobbs is a Visiting Scientist at the National Geospatial Intelligence Agency. For the last two decades his work has spanned a range of remote sensing and geospatial analysis applications areas, including land use / land cover mapping, unmanned aerial systems (UAS), hydrologic and hydrodynamic modeling, data visualization, remote sensing and geospatial data support for disasters, and teaching graduate level courses in remote sensing and related topics. In 2014 he held an appointment at the US Department of State in the Bureau of Intelligence and Research working with an interdisciplinary team within the Office of the Geographer and Global Issues. As part of the Humanitarian Information Unit (HIU) he engaged in interagency collaborations with the US Agency for International Development (USAID), the National Geospatial Intelligence Agency (NGA), the American Red Cross, the European Commission Joint Research Centre (JRC), the World Bank, and others focused on complex humanitarian crises.

Rapid Mapping Flood Inundation from the May 2020 Edenville, Michigan Dam Break

Dr. Dobbs' current research focuses on the nexus between flood modeling, elevation datasets, and remotely sensed imagery. Flooding has the greatest human and economic impact of all natural disasters, yet near real-time flood extent estimates remain a practical challenge to produce. As the quality of elevation data at all scales is rapidly improving, and the quantity satellite imagery that is acquired is rapidly expanding, the time is right for reimaging the way real-time information surrounding flood disasters can and will be derived. The research presented focuses on the application of novel techniques for rapid flood mapping of the Edenville, Michigan dam failure in May of 2020. These methods, using the Flood Inundation Surface Topology (FIST) Model, combine a least cost path algorithm applied to a directed graph (digraph) representation of digital elevation data along with ICEYE SAR satellite imagery to rapidly produce improved flood inundation data layers and flood depth grids.

Bryce Doerr

Dr. Bryce Doerr is a IC Postdoctoral Fellow in the Department of Aeronautics and Astronautics at MIT. He graduated with a Ph.D. in Aerospace Engineering and Mechanics from the University of Minnesota. His current work includes on-orbit robotic assembly of space structures and control of large collaborative swarms using Random Finite Sets. He also holds a position at the NASA Goddard Space Flight Center.

Motion Planning and Control for On-Orbit Assembly using LQR-RRT* and Nonlinear MPC

Deploying large, complex space structures is of great interest to the modern scientific world as it can provide new capabilities in obtaining scientific, communicative, and observational information. However, many theoretical mission designs contain complexities that must be constrained by the requirements of the launch vehicle, such as volume and mass. To mitigate such constraints, the use of on-orbit additive manufacturing and robotic assembly allows for the flexibility of building large complex structures including telescopes, space stations, and communication satellites. The contribution of this work is to develop motion planning and control algorithms using the linear quadratic regulator and rapidly-exploring randomized trees (LQR-RRT*), path smoothing, and tracking the trajectory using a closed-loop nonlinear receding horizon control optimizer for a robotic Astrobee free-flyer. By obtaining controlled trajectories that con- sider obstacle avoidance and dynamics of the vehicle and manipulator, the free-flyer will rapidly consider and plan the construction of space structures. The approach is a natural generalization to repairing, refueling, and re-provisioning space structure components while providing optimal collision-free trajectories during operation.

Neel Doshi

Dr. Neel Doshi is a postdoctoral fellow in the Department of Mechanical Engineering at the Massachusetts Institute of Technology. Neel graduated with a B.S. in Mechanical Engineering (2012) and a M.S. in Robotics (2013) from the University of Pennsylvania. He then earned his PhD (2019) from Harvard University. Neel's research focuses on using a combination of mechanical design and optimization-based control to improve the performance and reliability of autonomous robotic systems that interact with the world through physical contact. His current research is on developing robotic end-effectors and controllers for contact-rich manipulation. His graduate work used optimization to develop physics-based design, planning, and control tools for small legged robots such as the Harvard Ambulatory Microrobot. Neel has received a best paper award at ICRA '14 and has been a finalist for best paper awards at IROS '17 and ICRA '18. He is also the recipient of the Intelligence Community postdoctoral fellowship in 2019 and NDSEG graduate research fellowship in 2013. Finally, Neel is committed to increasing the participation of minorities in STEM and is currently helping develop an outreach program for his research group.

Planning and Control of Robotic Manipulation Primitives

In-orbit robotic satellite repair and assembly can both reduce the cost and increase the scope and efficiency of future space missions. This, however, requires the autonomous handling of a variety of objects in unstructured environments and is beyond the state-of-the-art in robotic manipulation. While there are several open challenges, my research focuses on the planning and control aspects of developing the necessary robotic manipulation skills. Inspired by the observation that complex manipulation tasks can often be decomposed into a sequence of simpler behaviors, I plan manipulations segmented into *manipulation primitives* such as grasping, pulling, pushing, or pivoting. Here I assume that the primitive sequence (e.g., pull then grasp) is provided by a teleoperator and present two novel algorithms for executing a variety of manipulation primitives.

Executing these primitives is challenging as they are hybrid, under-actuated, and stochastic. My first approach, hybrid differential dynamic programming (HDDP), addresses these challenges by planning a finite-horizon trajectory with a few contact switches and generating a stabilizing controller. I demonstrate that HDDP can be used to execute simple primitives such as planar pushing and planar pivoting. I find that, for these primitives, generating closed-loop trajectories using HDDP requires only a couple (one to two) hybrid switches, and therefore, can be done in a reasonable amount of time (one to five seconds). The second approach, iterative linear-quadratic regulation with hybrid-variations (iLQR-HV), generalizes HDDP to more complex primitive manipulations. This approach exploits the input affine structure of these primitives' mechanics to enable efficient planning of motions that require several contact switches. I evaluate the performance and computational cost of this framework in simulated ablations studies for several planar primitives.

My future work will focus on improving the computational efficiency of these algorithms to enable real-time re-planning for increased reliability and developing the mechanics of novel primitive manipulations for zero-gravity environments.

Daniel Drew

Dr. Daniel Drew is currently a postdoctoral scholar in Mechanical Engineering at Stanford University, working with Professor Sean Follmer. He will be starting as an Assistant Professor in Electrical and Computer Engineering at the University of Utah in Fall 2021. He received his Ph.D. in Electrical Engineering from UC Berkeley under the supervision of Professor Kris Pister in 2018. His research focuses on the development of autonomous insect-scale systems, bridging the worlds of robotics, microsystems, and design. His past work includes development of a flying millimeter-scale robot with no mechanical moving parts (the "ionocraft"), investigating new methods for resource-constrained communication and control, and studying how humans interact with swarms of insect-scale robots. Daniel received his B.S. in Materials Science and Engineering from Virginia Tech, an NSF Graduate Research Fellowship in 2013, and the Intelligence Community Postdoctoral Research Fellowship in 2019.

New Directions for Designing Effective and Efficient Microrobots

A world with an increasing number of data-driven decisions impacting health, industry, and the environment requires more effective means to gather data and take action. Swarms of millimeter- and centimeter- scale microrobots, which can deploy themselves, maintain themselves, and dynamically redistribute based on evolving field conditions, will be vital tools for stitching together this connected future. My work looks to nature for inspiration while developing the highly integrated systems required for functionality in the face of extreme resource scarcity, and also takes advantage of wholly artificial methods that leverage the mature fabrication techniques and decades of research into electromechanical device scaling from the semiconductor and MEMS industries to ensure nearer-term platform viability.

The performance of traditional mechanisms like spinning rotors begins to suffer at low Reynold numbers, and despite recent successes biomimetic (i.e., flapping wing) microrobotic fliers remain challenging to design, build, and control. In contrast, electrohydrodynamic (EHD) thrust is a propulsion mechanism that is silent, has no mechanical moving parts, is mechanically trivial to design, and theoretically simple to use for controlled flight. My dissertation work began an entirely new research direction: investigating EHD as a propulsion mechanism for insect-scale robots. Currently, I am investigating ways to improve the efficiency, thrust density, and ease of fabrication of these systems. My most recent research explores a smart composite microstructure fabrication method to demonstrate EHD jet arrays with folded electrodes that form tightly integrated high power density air jets.

Even with the best estimated propulsive performance, the payload mass and energy budget of projected insect-scale platforms is too limited to support much functionality at all. In nature, similar constraints have been overcome with not just high-performance components, but clever multi-functional integration. One example is the phenomenon known as stridulation, where insects use passive mechanical structures on their body to communicate, a well-known example of which is the chirping of crickets. I have recently begun to investigate mimicking this low resource overheard coupling between robotic communication and actuation. One project uses a centimeter-scale quadrotor platform; due to the low inertia and high RPM of airfoils at this scale, I have found that it is possible to send frequency-modulated data using the propeller noise itself in mid-flight.

Once new microrobotic platforms are developed there is still a challenge associated with making them useful as tools, as reliable human operation is already a significant barrier to use of much larger and more capable robots in the field. A recent project in the realm of human-swarm interaction uses a user-centered design approach and a real centimeter-scale robot swarm for development of a mixed-mode proximal control vocabulary.

Lisa Durbeck

Bradley Department of Electrical and Computer Engineering
Virginia Tech

Dr. Lisa Durbeck is an IC Postdoctoral Fellow at Virginia Tech in the Configurable Computing Lab. She received a B.S. equivalent in Computer Science from the University of California, Berkeley, an M.S. in Computer Science from the University of Utah with an NSF fellowship, and a PhD. in Computer Engineering from Virginia Tech as an NDSEG Fellow, Hume Center Fellow, and PEO International Scholar. Her research spans the fields of networks and programmable logic, with a particular interest in distributed processes and control. She was formerly on the research faculty at Virginia Tech and PI or co-PI of research funded by LANL and NASA-JPL in defect-tolerant scalable, programmable computing fabrics.

Scalable Incremental Partitioning of Sparse Stochastic Block Model Graphs

Graph partitioning, or clustering, is an NP-hard problem whose efficient approximation has long been a subject of interest and an area of progress. Methods have sought a balance between simplicity, correctness and accuracy, vice latency, computation cycles and memory required.

Limited memory size within contemporary computing environments, along with disk and network latency and other I/O restrictions, render this problem one of a long input stream partitioned using very finite computing resources. This favors an incremental or streaming approach to graph partitioning, where data is processed in small batches relative to the overall graph size, within a short time window of arrival at the processor, in a touch-once framework. This talk summarizes work on an incremental approach to streaming partitioning that tracks graph updates with a recently published lightweight proxy and triggers partition as the error associated with the group label assignments increases beyond a threshold. Little information is required, or kept. The talk includes an assessment of the proxy's efficacy and performance at handling minor graph changes during streaming input to a partitioner based upon spectral methods.

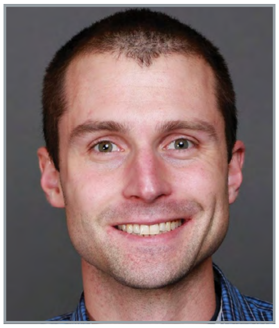
Evaluations use a public dataset and metrics from the DARPA/MIT Graph Challenge, which includes a set of synthetic Stochastic Block Model graphs of up to 5M nodes and 230M edges with known vertex cluster assignments, and a reference partitioner that serves as a baseline.

Mattias Fitzpatrick

Dr. Mattias Fitzpatrick is a IC Postdoctoral Fellow. He recently completed his Ph.D. in the Electrical Engineering department at Princeton University. In his Ph.D. he built lattices of superconducting circuits to study dissipative phase transitions and other nonlinear and quantum phenomena. In addition, he developed a novel approach to study effective hyperbolic and other curved lattices with superconducting lattices. He is the recipient of numerous teaching awards, including the “Distinguished Teaching Award” which is Princeton’s most prestigious teaching award. In addition, he is the recipient of the 2019 “Bede Liu Best Dissertation Award” which is given for the best dissertation from the graduating Ph.D. class. In his IC postdoc he has been working with nitrogen vacancy (NV) centers in diamond to develop novel sensing techniques for extracting real-time temporal and spatial correlations in magnetic field signals.

Charge State Dynamics and OD-ESR Contrast of Shallow NV Centers in Diamond

Nitrogen-vacancy (NV) centers in diamond can be used for nanoscale sensing with atomic resolution and sensitivity; however, it has been observed that their properties degrade as they approach the diamond surface. Here we report that in addition to degraded spin coherence, NV centers within nanometers of the surface can also exhibit decreased fluorescence contrast for optically detected electron spin resonance (OD-ESR). We demonstrate that this decreased OD-ESR contrast arises from charge state dynamics of the NV center, and that it is strongly surface-dependent, indicating that surface engineering will be critical for nanoscale sensing applications based on color centers in diamond. If time permits, I will also discuss how NV centers can be used to sense correlations in magnetic field signals, something which may be useful for understanding a variety of condensed matter systems.



Dodd Gray

Dr. Dodd Gray is a Postdoctoral Fellow in the Physical Optics and Electronics (POE) Group, led by Prof. Rajeev Ram within the Research Laboratory of Electronics at MIT. His research is focused on the physics of photonic and optoelectronic waveguide devices which roughly falls into three categories: (1) waveguide nonlinear optics for low power wavelength conversion, (2) cryogenic optoelectronic interfaces to superconducting electronics, and (3) integrated source development for stimulated Raman spectroscopy.

Dodd joined the POE group as a Postdoctoral Associate in April 2019 and began an ORISE Postdoctoral Fellowship in Oct. 2019. Prior to that he worked as a graduate student under the supervision of Prof. Hideo Mabuchi in the Applied Physics Department at Stanford University. There he developed a scanning probe instrument based on Raman spectroscopy to characterize domains arising from low-temperature phase transitions in $SrTiO_3$ and studied wavelength conversion in CMOS-fabricated silicon waveguide devices. Dodd previously worked in the POE group as both an undergraduate and master's student at MIT, developing modeling and experiment tools to study thermoelectric effects in light-emitting diodes.

Dodd holds degrees in Electrical Engineering from Stanford University, Ph.D. '19, and MIT, B.S. '10 and M.Eng. '11.

Hybrid CMOS-LiNbO3 Optical Frequency Comb Integrated with Trapped-Ion Optical Clocks

In this talk I will present ongoing work focused on the design and fabrication of integrated optical waveguides for efficient, broadband wavelength conversion and optical frequency comb (OFC) generation.

The ecosystem of photonic integrated circuit (PIC) platforms with optoelectronic functionality is rapidly evolving. CMOS photonics has matured to commercial viability and provides low-loss optical waveguides and resonators densely co-integrated with photodetectors and transistors for in-situ light detection, signal processing and feedback control. Meanwhile thin-film $LiNbO_3$ (TFLN) has emerged as a promising PIC platform compatible with wafer-scale photolithography, providing low-loss waveguides with nonlinear- and electro-optic functionalities complimentary to those available in CMOS. Combined, the capabilities of these two platforms are sufficient to realize a wide variety of complex chip-scale laser systems with reduced cost, SWaP and improved stability compared to fiber-optic and free-space alternatives.

In an effort to help bring OFCs and other advanced spectroscopic measurement tools out of the laboratory and into the field, our group is working to develop new components needed to interface CMOS with TFLN and other PIC platforms. Several remaining challenges must be addressed before integration of OFCs and other femtosecond pulsed laser systems can be practical. In particular, flexible dispersion engineering of integrated TFLN waveguides is needed for efficient broadband wavelength conversion, a critical ingredient for OFCs.

I will present an "inverse-design" approach to broadband dispersion engineering intended to address this need. In this approach, we optimize the geometry of dielectric perturbations surrounding a ridge waveguide to maximize the bandwidth of efficient second harmonic generation (SHG). Inspired by recent progress in integrated optical coupler design, this approach leverages the adjoint-field simulation method for efficient, simultaneous optimization of numerous geometric design parameters. I will also present recent experimental progress towards fabricating optimized broadband SHG waveguides, with a special focus on fabricating periodic ferroelectric domain structures in TFLN and characterizing them with a confocal SHG microscope. Finally, I will lay out the near-term research timeline for initial demonstration of bandwidth-optimized SHG waveguides.

Jason Gross

Dr. Jason Gross is an associate professor Department of Mechanical and Aerospace Engineering at West Virginia University (WVU). He received his Ph.D. in Aerospace Engineering from WVU in 2011, received his undergraduate degrees in Mechanical Engineering and Aerospace Engineering from WVU in 2007, and was WVU's Student Body President from 2006-2007.

From 2011 to December 2013, he worked as Research Technologist in the Near Earth Tracking Applications Group at Caltech's NASA Jet Propulsion Laboratory. His research focuses on robotic systems and unmanned aerial system with an emphasis on perception and localization. He directs the WVU Navigation Lab, is a coordinator of WVU's growing robotics program, and is the lead for WVU's Space Robotics Challenge 2 team. He is past recipient of an NGA New Investigator Program grant, AFOSR Faculty Fellowship, WVU Big XII Faculty Fellowship, and WVU Statler College Outstanding teaching and new researcher of the year awards.

Localization and Planning for a UAV/Robot Team in Subterranean Environments

We present the latest results on our NURI project that considers cooperative localization and planning for an autonomous unmanned aerial vehicle (UAV) and unmanned ground vehicle (UGV) team that is tasked with exploration of a subterranean environment. In particular, the presentation will start by providing an overview of the UAV and UGV systems and the GPS-denied localization algorithm for the UAV with respect to the UGV. We will then detail a UAV waypoint planning algorithm that has been developed to satisfy the mission›s exploration criterion while also reducing the localization uncertainty of the UAV. For both the localization and planning algorithms, we will present our results to date and the improvements we are currently exploring. We conclude the presentation by discussing our future plans for the NURI project.

Raoul Guiazon

Dr. Raoul Guiazon is a UK IC Postdoctoral Research Fellow working on "Artificial Behaviour Based Authentication for the Internet of Things" at the University of Leeds, UK. He trained as an engineer in electronics at ENSEA Paris - France, then completed an MSc in Communications and Signal Processing at Imperial College London in 2013. Subsequently, he was awarded a PhD from University College London for his work on "Interference as an Issue and a Resource in Wireless Networks" where he investigated the use of interference for security in IoT (Internet of Things) networks and its mitigation for increased data throughput. His work was funded by British Telecom (BT) and the Engineering and Physical Sciences Research Council (EPSRC).

In 2017 Dr. Raoul Guiazon joined the Experimental Quantum Information group at the University of Leeds UK, to investigate novel approaches to cyber-security, first by exploring Free space Quantum Communications and now by developing original authentication methods for connected devices. His current work is funded by the UK Government Office for Science via the Royal Academy of Engineering.

Intrusion Detection Systems for Sensor Networks

Cybersecurity is one of the main challenges faced by modern society. An ever-increasing part of our daily activities is conducted online or greatly relies on our ability to safely and reliably exchange data across remote locations. This reliance on communicating devices will only grow as the trend is moving towards autonomous devices and networks, with sensors and actuators that communicate without much human oversight over the Internet of Things (IoT).

As critical decisions are taken autonomously based on sensor data, the integrity of the messages coming from the sensors must be ensured. This is particularly important in applications such as self-driving vehicles, smart distribution networks or other national infrastructures where an incident can cost lives, money and generate tremendous environmental damage.

This presentation will review the current techniques used to detect data tampering in sensor networks and introduce a novel method that will complement these approaches to provide greater resilience against attacks.

Felipe Guzman

Dr. Felipe Guzman is an experimental physicist and electrical engineer specializing in space optical technologies, inertial sensing, novel optomechanical sensors and precision laser interferometry. He is the PI of the Laboratory of Space Systems and Optomechanics (LASSO) at Texas A&M University. His research group is a member of the international LISA Mission Consortium, and the LIGO Scientific Collaboration. He received his Bachelor's degree in Electrical Engineering at the University of Costa Rica, subsequently moving to Germany to obtain a Master's degree in Engineering Physics at the University of Oldenburg in Germany, and a Ph.D. in Physics from the Max Planck Institute for Gravitational Physics, where his doctoral research focused on the development of optical technologies for LISA, LISA Pathfinder and GRACE follow-on. He was awarded a NASA Postdoctoral Program (NPP) fellowship at NASA Goddard Space Flight Center and later performed as Senior Research Associate at the National Institute of Standards and Technology (NIST), and Research Group Leader at the German Space Agency (DLR) in collaboration with the University of Bremen. Prof. Guzman joined the faculty of the Department of Aerospace Engineering at Texas A&M University as an Associate Professor in Fall 2020.

Optomechanical Gravimeters and Gravity Gradiometers

Felipe Guzman, Adam Hines, Logan Richardson, Hayden Wisniewski, Andrea Nelson

Gravitational acceleration provides unique measurement opportunities to identify natural and man-made phenomena at global scales with signatures that are extremely difficult to mask due to their nature. Changes in these gravitational signatures and their gradients over certain distance baselines can reveal strategic information that is relevant to national security. Such gravitational observations are currently conducted with commercial gravimeters and gravity gradiometers that consist of complex mechanical structures operating large, inertially sensitive test and cumbersome displacement readout systems.

In our NGA/NURI program, we are currently developing highly compact, portable, and cost-effective optomechanical gravimeters and gravity gradiometers of exquisite sensitivities, building upon significant advances in the area of optomechanical inertial sensing technologies over the past few years. These technologies consist of low loss and highly stable monolithic mechanical oscillators that we combine with miniaturized laser-interferometric displacement sensors, enabling us to achieve extremely high performances in gravitational sensing in unprecedented form factors.

We will present our technology concepts and recent laboratory results towards the realization of novel optomechanical gravimeters and gravity gradiometers.

David Harris

Dr. David Harris is a researcher in Psychology interested in skill acquisition, cognitive training and performance states (ranging from breakdowns under pressure to peak flow experiences). In particular, he is interested in the mechanistic role of eye movements and visual attention in these areas. He has applied his research to a range on environments, including surgery, the military and gaming. His current work focuses on virtual reality and assessing the effectiveness of virtual environments for training cognitive skills.

Dr. Harris completed his PhD in 2017 under the supervision of Prof Mark Wilson and Dr Sam Vine at the University of Exeter, where he examined the state of flow and how visual attention contributes to peak performance states. Since then he has worked on research projects examining observational learning in robotic surgery (2017) and held subsequent post-doctoral positions working on eye movement and cognitive training for the military (2018) and eye movement training for children with DCD (2018) with Prof Wilson and Dr Vine. In 2018, he was awarded a Royal Academy of Engineering UK IC Post-doctoral Fellowship to examine the effectiveness of virtual reality for training cognitive skills in defense and counter-terror personnel.

Evaluating Virtual Reality Training of Cognitive Skills for Counter Terror Policing

Virtual reality, augmented reality and mixed reality technologies are gaining in popularity as a training tool in many industries. Virtual environments (VEs) are a group of technologies which allow users to interact with a simulation of a real environment, in real time using their own senses and motor skills. Research indicates that VEs provide benefits for user engagement, which can lead to greater uptake of training. VEs also allow more effective and varied training methods. Where VEs may provide the greatest opportunity, however, is in training for highly complex or dangerous situations that could not otherwise be practiced – such as for Defence and Security. VEs provide trainers with the opportunity to deliver high-risk, safety critical, high fidelity training, at low cost, and without real risk to trainees. Simulation training has been used effectively in many domains, including policing, but head mounted virtual reality may serve to further enhance learning and knowledge retention through increased realism and immersion. The current project aims to design, build and test a virtual training environment for police house searches and response to terrorist incidents. Crucially, for virtual training to realise its potential as a training device, an empirical evidence base supporting its effectiveness is required. This project aims to develop that evidence base.

To progress the design of effective virtual training environments it is first necessary to establish the skills and capabilities that can be trained and enhanced in a VE, and the effect that this training has on real-world performance (i.e. transfer of learning). Consequently the initial work of the fellowship aimed to assess how cognitive skills like visual search can be trained in VR. Based on principles derived from cognitive training, a gamified search training VR application has been developed and tested. This prototype application has been further developed into a larger search house for use with the London Metropolitan Police. This training application will be embedded within training procedures and tested in comparison to training as normal.

Preston Hartzell

Dr. Preston Hartzell is a Research Assistant Professor in the Department of Civil & Environmental Engineering at the University of Houston, where he also completed his PhD in 2016. Prior to his current appointment, he was employed as a Professional Land Surveyor with an engineering consulting firm.

Preston's research interests include radiometric and geometric characterization and calibration of topographic lidar and passive imaging sensors, spatial data registration, and uncertainty propagation.

Robust Confidence Measures for Multi-Temporal 3D Spatial Change Detection

Multi-temporal spatial data, in the form of 3D point clouds or 2.5D raster products, is increasingly abundant as scenes and landscapes are repetitively measured. Application of semi-automated change detection or spatial deformation measurement methods have naturally followed. Typical examples include differencing digital surface models (DSMs) derived from 3D point clouds to produce 1D vertical change maps, image correlation techniques applied to DSMs to generate 2D horizontal deformation products, and iterative closest point (ICP) algorithms applied to point clouds for measuring 3D spatial deformation. An interesting aspect of these temporal change products is that estimates of uncertainty in the reported change or deformation are rarely reported, with instances of classical methods for propagating source data uncertainty through the change measurement algorithms even more sparsely found.

We report on progress, mid-way through a two-year grant, to develop both the source uncertainties and mechanisms for propagating them into spatial change products via classical total propagated uncertainty (TPU) methods. Our focus is on multi-temporal DSMs derived from airborne lidar point cloud data for detecting horizontal change via windowed image correlation and vertical change through raster differencing. On the source uncertainty side, we will review current work to remove some of the barriers to generating per-point TPU estimates for lidar point clouds by removing the requirement for raw sensor observations, e.g., lidar range, scan angle, and original sensor trajectory data. For spatial change detection products, we report on the performance of an algorithm developed to propagate DSM vertical uncertainties though image correlation to produce uncertainties on the derived horizontal vectors that quantify the deformation that has occurred between temporally spaced DSMs.

Future work will address two main areas. First, the gap between point cloud uncertainties and the vertical cell uncertainties in DSMs generated from the point clouds must be bridged or, potentially, circumvented. Second, measurement of spatial change requires the temporal datasets to lie in a common coordinate reference system, i.e., to be tightly registered. However, this is challenging in the presence of spatial deformation. We will investigate adapting one or more methods used for point cloud registration in the face of spatially variable temporal motion to the DSM products used in the current work.

Tim Helps

Dr. Tim Helps received his MEng in Mechanical Engineering from the University of Bristol in 2010. He continued his studies in bio-inspired robotic locomotion, focusing on reducing the energy costs of running and hopping robots, and was awarded his PhD in 2015. He then worked on the Wearable Soft Robotics for Independent Living project, a.k.a. The Right Trousers. In this project he developed soft robotic technology for assistive clothing to improve the mobility and independence of older adults and people living with disabilities; the assistive clothing provides robotic power to help with walking, sit-to-stand, and stair climbing. The project received wide press coverage including BBC News, The Times, The Guardian and The Daily Telegraph.

He is now an UK IC Postdoctoral Research Fellow with the Royal Academy of Engineering, developing insect-inspired semi-autonomous robots for remote missions such as intelligence gathering, humanitarian disaster relief and industrial repair.

His research interests include robotic locomotion, artificial muscles, soft sensors, and assistive orthotics.

Insect-Inspired Semi-Autonomous Agents for Remote Missions

Insects exhibit many incredible capabilities in terms of locomotion, adaptability and task-specific performance. However, until now, these abilities have largely been overlooked in artificial devices. Small, soft, semi-autonomous robots with biologically comparable performance could revolutionise intelligence gathering, remote intervention, humanitarian disaster relief, and many other fields.

Currently, fundamental technology challenges limit the performance of small robotic agents. Traditional robots with wheeled or tracked morphologies are not suited to unstable terrain and tightly confined spaces. Alternative locomotion methods more suited to these environments such as worm-like and legged locomotion have been investigated in the laboratory but rarely executed in the field. Similarly, traditional actuators are limited in their performance; no devices exist which exceed or even match animal muscle in every performance aspect.

This project aims to solve these challenges through three complementary research themes. First, insect characteristics, including biology, biomechanics and behaviour will be investigated, and insect-inspired locomotion strategies will be examined for suitability to micro-robotic systems. Second, new artificial-muscle technology will be developed, building upon fundamental physical phenomena and taking inspiration from biology. Finally, research from themes 1 and 2 will be combined to develop high-performance micro-robotic demonstrators, enabling navigation over rugged terrain and through tightly-confined environments.

Through these ambitious research themes, this project will deliver a step-change in semi-autonomous micro-robot performance and provide a jumping-off-point towards fully-autonomous, independent robotic agents which can perform mission-critical intelligence gathering and intervention tasks.

Adam Hines

Adam Hines is an aerospace engineering PhD student at Texas A&M University, researching opto-mechanical resonators for use in gravimeters and inertial sensors under Dr. Felipe Guzman in the Laboratory of Space Systems and Optomechanics (LASSO). He completed his undergraduate education at the University of Minnesota – Twin Cities with bachelor's degrees in physics and astrophysics in 2018. He then enrolled in a physics PhD program at the University of Arizona in 2018 and transferred to Texas A&M University in 2020.

Optomechanical Inertial Sensors for Gravimetry

Adam Hines, Logan Richardson, Hayden Wisniewski, Andrea Nelson, Felipe Guzman

Optomechanical resonators are a promising candidate for the development of novel gravimeters that are cost-effective, portable, and have competitive sensitivity compared to commercially available options. Monolithic fused silica resonators have low internal losses, leading to exquisite acceleration noise floors while being compact and lightweight. When coupled with high-precision laser interferometry, we anticipate that optomechanical sensors can achieve sensitivities below 10^{-10} m $s^{-2}/\sqrt{Hz}$ in the sub- Hz regime. In this talk, we present on the advantages of optomechanical gravimeters and the theoretical analysis that makes them an exciting option for gravimetry. We also present preliminary results from the development of such an optomechanical gravimeter.

Edmund Hunt

Dr. Edmond Hunt is working on taking insights from collective animal behavior and finance into applications in swarm robotics, such as monitoring hazardous environments. Dr. Hunt is looking forward to translating his research into real-world robot demonstrators.

Dr. Hunt is based in the Department of Engineering Mathematics at the University of Bristol, UK, where he is a member of the collective dynamics group. He undertakes some experimental work at the Bristol Robotics Laboratory. He is part of Dr Sabine Hauert's 'swarm engineering' group.

In 2017, he spent a year at the University of California, Los Angeles (UCLA) Ecology & Evolutionary Biology Department, working on animal social networks with Prof Noa Pinter-Wollman.

Dr. Hunt's Bristol PhD research was concerned with the exploration and decision-making behavior of house-hunting ants, within the field of behavioral ecology and complexity sciences. After initially studying physics at Imperial, he studied economics at Oxford and worked in banking regulation (risk management) in London and Brussels.

Risk-Sensitive Robot Swarms for Effective Environmental Monitoring and Anomaly Investigation

My fellowship is toward the topic: "Application of sensing networks for situational awareness and early detection of threats". It would be useful to develop a capability to rapidly deploy sensors, that navigate to a location and transmit information to a control centre and remain discreet. The potential application and benefit for this is extensive: for example, monitoring construction sites overseas; monitoring complex buildings; detecting environmental conditions; detecting the presence of CBRN material; or to improve security in a wide range of scenarios such as following a major incident.

I am making progress on this challenge using the field of swarm robotics. This is inspired by animal collectives such as ant colonies which use self-organization to achieve characteristics of scalability, flexibility and robustness. One proposed application for swarm robotics is environmental monitoring, creating a dynamic network of intelligent sensors that can adjust spatial position as required to create situational awareness and allow early detection of threats. Such monitoring usually requires coverage of large areas, that can be highly variable or unpredictable, and often hazardous or risky.

Yet little work has been done in swarm robotics control algorithms to consider how to manage this risk effectively at the level of the whole swarm: how to ensure that individual robots make suitable decisions to enter risky areas to gather information, or hold back and avoid untimely destruction of the swarm. Autonomous decisions will depend on both the individual robot's immediate environment and the state of the swarm as a whole: the potential for informational gain will need to be 'risk-weighted' to the viability of the swarm, in relation to its communication network properties, for example.

I am drawing upon two research fields to help inspire this development of autonomous swarm risk management. The first is behavioural ecology, which investigates how animals undertake risk-sensitive behaviours such as foraging in the presence of predators, adapted to the particular characteristics of their environment. This includes the growing field of animal 'personality' research which considers how differences in characteristics such as boldness allow groups to adapt to local risk environments. The second is the field of financial risk management, which considers how exposure to financial loss from e.g. changing market conditions can be controlled through suitable portfolio composition of safe and risky assets.

In addition to developing risk-sensitive control algorithms, I plan to perform field demonstrations at a university farm facility. This will include prototyping of some simple micro ground vehicles, which will be used to obtain sensor coverage of an area containing simulated risks and environmental anomalies that invite further investigation.

Rachel Jones

Rachel Jones is a Visiting Scientist at National Geospatial-Intellilgence Agency (NGA) through the Oak Ridge Institute for Science and Eduction (ORISE) and a PhD candidate in Geological Engineering at Missouri University of Science and Technology. The focus of her research is Geospatial Engineering using remote sensing methods for groundwater potentiality in post-civil war Uganda. Her humanitarian research is focused in east Africa using remote sensing and geoanalytics for refugee movements, mass atrocities, and counter-human trafficking in complex crisis theaters. She assists Harvard Humanitarian Initiative (HHI) where she has trained international humanitarian aid workers in armed conflict/natural disaster complex crisis simulations to detect sex trafficked individuals within refugee movements.

Lineament Extraction from Sar and Magnetometry Fused Data Products for Groundwater Potentiality Exploration: A Case Study in Gulu District, Uganda

Lineament extraction of fault networks from remotely sensed data products is common practice in GIS and RS applications and is used in the characterization of hydrogeological regimes. Fractures are conduits for fluid flow and an important source of aquifer recharge. Existing techniques utilize single data products which may not always present a definitive classification of fractures, folds, or faults in areas where the terrain obscures lineaments expressions. SAR is commonly used for the development of lineament maps, however curvilinear surface hydrologic features are often detected simultaneously with fracture networks. Surface drainage patterns must be isolated from fracture networks to more accurately characterize surface recharge regimes. Magnetic geophysical data is commonly used to map fracture networks as well, but does not detect all of the lineaments within a fracture network. This research fuses various Alos Palsar L-Band polarimetric decompositions with various magnetic geophysical products to generate a lineament map that maximizes the number of lineaments detected while excluding hydrologic stream systems from the end product. PauliRGB, Van Zyl, and circular SAR products are used in combination with the magnetic analytic signal, horizontal gradient, and first vertical derivative to evaluate the most effective combination of data fusion products for lineament detection.

Juliette Jordan

Dr. Juliette Jordan is currently an Intelligence Community Postdoctoral Fellow working under the supervision of Dr. Colleen Doherty in the Structural and Molecular Biochemistry Department at North Carolina State University. Juliette received a B.S. in Biology in 2009 and an M.S. in Biology in 2011, both from Georgia Southern University. Juliette worked as an EHS intern from 2011 to 2012 and then as a buyer from 2012-2015 for Mitsubishi Hitachi Power Systems, a turbine manufacturer, during which she earned an MBA from Georgia Southern University. She received her Ph.D. in Environmental Toxicology from Texas Tech University in the Fall of 2018, where her graduate work focused on the phenotypic and physiological effects of carbon nanomaterials on crops such as tomato and cotton. As an Intelligence Community Postdoctoral Fellow, she is developing methods to detect carbon nanostructure detection using crops by monitoring physiological as well as molecular responses in maize. She is exploring how external factors, like time of day measurement is taken, and varying environmental conditions to affect detection methods. She employs gene expression measurements, metabolite and volatile organic compound measurements, imaging techniques, and other monitoring methods to evaluate plant responses to carbon nanostructures. Through this research, she aims to find the best indicators that will facilitate real-time monitoring of carbon nanostructures using plant responses.

Early Detection of Chemical-Induced Temporal Stress Signatures in GMO and Non-GMO Maize

As sessile organisms, plants must respond rapidly to even the most minute changes in the environment. Plants sense and respond to subtle perturbations through alterations that can be evaluated with molecular and imaging analytical techniques. Therefore, plants can be used as a sensor for the presence of unwanted chemicals. One chemical class of concern are engineered nanomaterials (ENMs) and, in particular, carbon nanostructures. Carbon nanostructures are widely used due to their unique chemical, physical and electrical properties. Current uses of carbon nanostructures include wastewater treatment, combustion manufacturing, and medical, pharmaceuticals, and agricultural devices. They can be released into the environment intentionally and unintentionally. Types of carbon nanostructures include fullerenes, carbon nanotubes, and graphene. Carbon nanostructures can be functionalized or non-functionalized in order to meet consumer product needs. This project investigates using plants to monitor the environment for the presence of carbon nanostructures. The whole plant effects of carbon nanostructures are examined on both GMO maize and conventional maize with the use of mass spectrometry, RNA sequencing, and imaging technology. The approach employed monitors the temporal pattern of spectral and molecular signatures to enhance the ability to detect carbon nanostructures. One aspect of this project is determining the effects of carbon nanostructures on the composition of secondary plant metabolites. Secondary plant metabolites are phytochemicals that can be either non-volatile or volatile. Of particular interests are the changes in volatile organic compounds (VOCs) emitted by plants exposed to carbon nanostructures. VOCs can be measured at a standoff distance allowing monitoring of a field based on the changes in plant VOC emissions. We are quantifying the VOC profile changes in response to carbon nanostructures throughout a 24-hour period. The release of plant compounds is time of day dependent and we will determine if there are VOC profiles that change in response to carbon nanostructures and the time of day they need to be monitored. This information may provide signatures that indicate the presence of carbon nanostructures. Another emphasis of this project is to identify the carbon nanostructure induced molecular changes at the transcriptional and metabolite level. Currently, these changes cannot be monitored at a distance, however, a better understanding of the effects of carbon nanostructures on plant metabolism will provide new targets for monitoring and the opportunity to design targeted sensors. Imaging techniques and other carbon nanostructure detection techniques will later be explored. The end goal of this project is to use plants as indicators through monitoring the phytochemical time-ratios to alert to the presence of carbon nanostructures in the environment.

Deepti Joshi

Dr. Deepti Joshi is an Associate Professor of Computer Science at The Citadel, the Military College of South Carolina. Her research interests include spatio-temporal data analytics, integrating wide variety of data for story building purposes, using data-driven approaches to model complex phenomena, and natural language processing. She is currently working in the domains related to anticipating social unrest and understanding natural disaster response. She also works extensively in the K-12 space to help the teachers learn how to integrate computing the core-disciplines. This is work is funded through the NSF STEM+C and other state grants. She earned her PhD in 2011 from University of Nebraska-Lincoln (UNL) in Computer Science with focus on data mining techniques. She received the Faculty Excellence Award for Research in 2018 from The Citadel.

Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model-and Data-Driven Approaches

Social unrest against government or state (in)actions fueled by socio-demographic or environmental factors is a great concern because of its potential impact on security and stability of any society at local, national, regional, and global scales. Of particular interest is the understanding and anticipating the cycles of contention for unrest that is challenging due to the ever-increasing volume, speed and variety of data (and noise) that is being generated, and the varying granularity of data (temporal, spatial and individual). Our *long-term goal* is to address these challenges by developing an *integrated model-driven and data-driven framework to anticipate social unrest events in a broad range of countries*. Model-driven approaches leverage human expertise, and social science-based theories to illuminate key factors—correlates and causes—underlying social unrest. Data-driven approaches exploit immediacy and comprehensiveness of data to discover patterns associated with unrest, help expand the models powered by algorithms, and inspire the model-driven social science efforts. Our goal is to examine the relationship of diverse thematic data that are increasingly becoming available in digital form including *Socio-demographic, Cultural, Environmental, Infrastructure, Geographic, Economic (SCEIGE) data*.

Currently we are 1) building our databases for SCEIGE data, unrest event data, and 5W analysis; 2) identifying and exploring SCEIGE factors that may behave as fuel or trigger for unrest events; 3) prototyping and evaluating an agent-based simulation framework for social unrest anticipation based on SCEIGE data; 4) developing a ground truth dataset for 5W analysis for the unrest events reported in news articles; and 5) establishing and validating novel algorithms that uses natural language processing and machine learning to accurately identify the location of unrest events.

So far we have 1) collected, curated, and analyzed data on various SCEIGE factors and proxies, including both news articles and existing datasets such as DesInventar, ACLED, ICEWS, GDELT, Census Data, CHIRPS data.; 2) performed exploratory and confirmatory factor analysis for various factors to discover their relationship with occurrence of protest; 3) developed a prototype multiagent simulation adopting a disease spread model to model how social unrest spreads spatially and over time; 4) extended our work on 5W analysis, in particular, to focus on improving our accuracy of extracting locations for social unrest events from newspaper articles; and 5) identified and will continue to evaluate the use of the Standardized Precipitation Index (SPI) as a proxy for agricultural productivity in the regions of interest. The current focus is on India. We will be expanding our scope to include Pakistan, Bangladesh, and Iraq in the next year.

Michael Ketterer

Dr. Michael E. Ketterer obtained his primary and secondary education in Buffalo, NY, and received a B.S. in Chemistry from University of Notre Dame in 1980. He pursued graduate studies in electron transfer and interfacial chemistry at the University of Colorado under the direction of Prof. Carl A. Koval, receiving a Ph.D. in analytical chemistry in 1985. After brief employment as an industrial electrochemist, he worked from 1987-1993 at USEPA's forensic laboratory where he developed interests in isotope geochemistry and mass spectrometry. He is currently Professor Emeritus of Chemistry and Biochemistry at Northern Arizona University, and is an adjunct instructor in the Chemistry and Biochemistry Department at University of Denver; Michael is currently an NGA visiting scientist working under the mentorship of Dr. James A. Jordan.

Uranium Isoscapes: Examining the Geospatial Distribution of Natural and Anthropogenic Sources

Isoscapes provide an interpretive summary of the geospatial distributions of isotope compositions for selected elements on a local, regional or continental scale; uranium is an element that exhibits information-rich variance in its isotope compositions. There are four long-lived radioisotopes of this element: ^{234}U, ^{235}U, ^{236}U and ^{238}U. The isotopes ^{235}U ($t_{1/2}$ = 7.0 x 10^8 y, 0.72% abundance in Nature) and ^{238}U ($t_{1/2}$ = 4.5 x 10^9 y, 99.27%) are primordial; ^{234}U ($t_{1/2}$ = 2.5 x 10^5 y, 0.005%) is an intermediate in the ^{238}U decay series, and ^{236}U ($t_{1/2}$ = 2.3 x 10^7 y, < 10^{-8} %) is a principally synthetic isotope formed via neutron irradiation of ^{235}U. Naturally occurring uranium exhibits relatively consistent, predictable isotope compositions; the $^{238}U/^{235}U$ atom ratio varies by only about 0.2% relative in Nature owing to small mass-dependent and mass-independent fractionation effects.

Decades of work have demonstrated that disequilibria develop between ^{234}U and ^{238}U under open-system conditions. In rigorously closed systems, equal activities of ^{234}U and ^{238}U are present, corresponding to a $^{234}U/^{238}U$ atom ratio of 0.000055. However, when U-containing minerals are in contact with the atmosphere and water, selective leaching and alpha recoil processes generate consistent excesses of ^{234}U in aqueous phases; $^{234}U/^{238}U$ ratios may be elevated by as much as tenfold vs. the secular equilibrium condition. Natural variations in $^{234}U/^{238}U$ ratios have been used to examine mixing between multiple water sources. The systematic variation in $^{234}U/^{238}U$ has also been successfully used to distinguish between U contamination in the hydrosphere resulting from natural weathering vs. technological processing of naturally occurring radioactive materials. Isotope mixing models demonstrate whether or not U is accountable for by simple two-component mixing, or whether a more complex mixture of sources is present.

Uranium isotope compositions are also affected by anthropogenic processes; near many nuclear installations, a local or regional pattern of altered isotope composition is evident from mixing between small quantities of "enriched" or "depleted" uranium with the relatively large background of naturally occurring U. Many types of media (water, soil, biota) are used for sensitive detection of recent airborne and waterborne releases of non-naturally occurring U. In addition to variations in $^{235}U/^{238}U$ and $^{234}U/^{238}U$ stemming from isotope enrichment in the nuclear fuel cycle, most of the U associated with nuclear facilities exhibits significant ^{236}U, stemming from the Cold War era use of "recycled U" recovered from Pu production reactors. The isotope ^{236}U is also present in fallout from 1950's-1960's atmospheric nuclear weapons testing, and it is essential to deconvolute the ubiquitous "fallout" baseline vs. that stemming from a site-specific source.

This presentation will summarize how U isotope systematics are applicable in evaluating the geospatial patterns arising from natural and anthropogenic effects. As part of the author's Visiting Scientist appointment, we have generated a dataset of $^{234}U/^{238}U$ atom ratios in ~ 200 water samples; ^{234}U – ^{238}U disequilibria are useful in distinguishing hydrological provinces.

Laura Kim

Dr. Laura Kim received her B.S. in chemical engineering (2013) and Ph.D. in materials science (2019) from California Institute of Technology as a National Science Foundation Graduate Fellow under the supervision of Professor Harry Atwater. Her doctoral research focused on understanding light-matter interactions in two-dimensional materials ranging from mid-infrared nanophotonics to ultrafast phenomena in graphene. She is currently an IC Postdoctoral Fellow at MIT with Professor Dirk Englund. Her current research involves interfacing nitrogen vacancy centers in diamond with nanophotonic and plasmonic structures to develop new nanoscale quantum sensing strategies.

Plasmonic Quantum Metasurfaces Using Nitrogen-Vacancy Ensembles

Nitrogen vacancy (NV) centers in diamond have emerged as a leading platform for solid-state quantum sensors with coherent times exceeding one second even at room temperature. The ability to optically measure quantities such as electric field, magnetic field, and temperature makes the NV system appealing for a wide range of applications ranging from biomedical devices to geology and navigation devices. A particular area of focus has been on microscope imaging sensors, which take advantage of the atomic length scale of the diamond color center. The central challenge remains in optimizing sensitivity per area: the smaller the spatial resolution, the better the signal-to-noise ratio. We report a quantum sensing metasurface consisting of periodic arrays of plasmonic nanostructures, which exhibit a large local field enhancement at the subwavelength scales and long interaction times provided by Q-factor of 878 when coupled with Rayleigh-Wood anomalies of the grating structure. This planar sensing surface boosts sensitivity via several ways: probing the infrared singlet transition with absorption rather than fluorescence for efficient collection, using homodyne measurements to achieve unity contrast, and scaling to large imaging surfaces. By combining these aspects, we demonstrate sub-nT $Hz^{-1/2}$ sensitivity per 1- sensing area, which can enable spatially-resolved NMR chemical detection and nanoscale imaging of quantities of interest, such as magnetic field, strain, and temperature.

May Kim

Dr. Kim May is a research associate at the Ion Storage Group of the National Institute of Standards and Technology (NIST) in Boulder, CO. Her research focuses on atomic clock comparisons for applications in quantum sensing and insights into quantum physics. Since her appointment in 2018, she has been involved in experimental efforts for comparisons between two aluminum ion clocks, and between an aluminum ion clock and an ytterbium lattice clock, a collaborative effort with the Optical Frequency Measurement Group at NIST. She has also been involved in collaborations with Sandia National Laboratory in simulating a multi-ensemble clock protocol for improved stability. With the IC Postdoctoral fellowship, adaptive optimization techniques will be adopted to develop clock servo algorithms to stabilize the frequency of the clock laser and implement it in the control system to improve the stability and reliability of atomic clocks. Previously, from 2016-2018, she was a postdoctoral research associate at Purdue University, where she led the effort to trap an array of atoms above a nanophotonic waveguide with strong atom-guided mode coupling to realize a many body system with long range interaction. She received a PhD in physics from Northwestern University in 2015, where she studied collective effects of atoms and their application in quantum computing and precision measurement.

Improving the Stability of Atomic Clocks Using a Multi-Ensemble Protocol and Adaptive Optimization with a Servo Feedback Scheme

Optical atomic clocks benefit from high transition frequencies, narrow transition linewidths, and small systematic frequency shifts. Besides their potential for replacing cesium microwave clocks to redefine the SI second, they provide sensitive measurements as quantum sensors for applications such as relativistic geodesy, limits on variations in fundamental constants and local Lorentz symmetry violation, and insights in quantum physics. Atomic clocks are also ideal candidates for quantum computing since they utilize extremely stable transitions, a key element in maintaining coherence during qubit operations. In this presentation, I will discuss stability as a measure of the clock performance, and how it can be improved using a multi-ensemble protocol. Lastly, I will show how further improvement can be obtained in the future using adaptive optimization techniques to develop a clock servo algorithm for optimal laser frequency feedback.

Byong Kwon

Dr. Byong Kwon ("BK") is a US Intelligence Community Postdoctoral Research Fellow in the Space and Terrestrial Robotic Exploration Laboratory at the University of Arizona developing artificial intelligence and bio-inspired algorithms for space applications. From May 2017 through April 2018, BK was a USAID – Arizona State University Global Development Research Scholar in Bogota, Colombia engaged in humanitarian demining research and science, technology and innovation capacity development with the Colombian National Army. From 2013 through 2017, BK served on the Education Committee at the Society for Industrial and Applied Mathematics. BK obtained his PhD in Applied Mathematics for the Life and Social Sciences from Arizona State University (2019), and Bachelor (2012) and Master of Sciences (2015) in Mathematics from George Mason University.

Neural Tissue (ANT)-Controlled Robotic Teams for Spatial Structure Assembly/Inspection/Repair

Currently, the only way to assemble, service or repair large space structures on-orbit is through a robotic spacecraft teleoperated from a base station, and a key task among these activities is the careful inspection of the target structure. A promising alternative to a teleoperated robotic spacecraft is an autonomous multi-robot team that can engage in, and increase the efficiency of such activities. To achieve this goal, we need an autonomous, multi-robot controller for complete, coverage path planning (CPP) for space applications. In this presentation, we propose the Artificial Neural Tissue (ANT) robotic controller, and a new training algorithm, Neuronal Regularization and Optimization (NRO) Learning, for solving the CPP task. Inspired by neuromodulation in the brain, ANT is an artificial neural network-based controller with a sparse, variable network topology and adaptive activation functions. NRO Learning employs ANT's features to create assemblies or hubs of heterogenous artificial neurons to solve the CPP task. Besides CPP, we plan to extend ANT and NRO Learning in future works to conduct multiple tasks needed for on-orbit assembly, servicing and repair.

Christopher LaMonica

Christopher LaMonica, PhD, is a Professor of Government at the US Coast Guard Academy, where he has been teaching since 2009. A dual French-American citizen and graduate of the Harvard Kennedy School and Boston University, Dr. LaMonica has also taught in France and New Zealand. Author of *Local Government Matters: The Case of Zambia* (2010) and related works, his areas of teaching and research include the history and politics of Africa, and port security, local and coastal governance in sub-Saharan Africa. He is currently working on a textbook for CQ Press entitled *African Politics: Frameworks for Analysis.*

Exploring the Links Between Food Insecurity and Maritime Crime in Coastal West Africa

Karina Lorenz Mrakovcich and Christopher LaMonica, US Coast Guard Academy

West Africa's coastal communities continue to rely on fish as a primary source of protein and that is a problem: scientists and fisheries experts are now speaking of a complete collapse" of the Gulf of Guinea (GoG) region's fisheries sector this year, in 2020. The growing desperation among GoG fishers resulting from fish stock decline and concomitant income and food insecurity has led, as elsewhere, to opportunistic and increasingly coordinated maritime crimes in the form of piracy, drug smuggling, and human trafficking, to name a few. This study considers circumstances in Ghana and Senegal, specifically, where politicians and governing institutions remain focused on supporting the expansion of the fisheries sector, in return for political support, rather than contemplate other more sustainable policy options for improving food security. Illegal, Unregulated and Unreported (IUU) fishing is the norm among the region's small-scale canoe fishers, who openly and routinely engage in undocumented transshipment of fish, the illegal use of chemicals and dynamite to catch fish, and the use illegal gear. Trawling vessels are often owned by foreign interests who appear to comply with local laws by registering their vessels locally and hiring a 75% local crew. But dialogue with local authorities revealed to us that trawlers routinely violate fishing laws; fines, though (selectively) imposed, are usually "negotiated" for minimal payments, often via Alternative Dispute Resolution methods, due to the understood ineffectiveness of the local courts and other enforcement authorities. Local norms routinely include disregard and blatant avoidance of weak law enforcement authorities. Moreover, foreign interests are known to collude with local authorities to take full advantage of these circumstances in order to maximize their catch. This study spells out why West Africa's land-centered leadership needs to better appreciate the significance of the maritime domain to the region's economic well-being and concludes that there are fisheries management techniques that can offer effective ways to help replenish the region's fish stocks, thereby helping to reduce rates of opportunistic GoG maritime crime. Through interviews, field observations, quantitative and spatial analyses, we compare recent efforts of the governments of Ghana and Senegal to implement new fisheries management techniques, to include Closed Fishing Seasons, in a desperate attempt to find solutions to this crisis.

Luce le Gorrec

Dr. Luce le Gorrec obtained her Engineer master's degree in computer science and Applied Mathematics from the National Polytechnical Institute of Toulouse, France, in 2016.

From September 2016 to October 2019, she was a PhD student at IRIT (research institute in computer science, Toulouse), supervised by Sandrine Mouysset and Daniel Ruiz. Dr. le Gorrec's main focus was to develop a spectral algorithm to detect block structures within matrices, which she extensively used to detect communities within networks. Her research interests are thus mostly linear algebra (especially spectral methods and matrix scaling) and networks (especially spectral graph theory and quality measures for community detection). During her PhD, she was a teaching assistant in applied mathematics at the Ecole d'Ingénieurs ENSEEIHT.

She obtained her PhD in October 2019, she is currently working under the supervision of Dr. Philip Knight, as a UK IC postdoctoral fellow at the University of Strathclyde, to develop algorithms to perform scalable partitioning of large complex networks.

Scalable Partitioning of Large Complex Networks

By mapping local level elementary interactions between data, networks provide a powerful template that enables one to analyse emergent behaviour in complex systems. As the volume of data recorded continue to expand so the size of complex networks increases dramatically, requiring the development of ever more efficient methods of analysis.

In this context, the aim of our research project is to develop algorithms to efficiently partition large complex networks into communities, identified as groups of nodes sharing lots of mutual connections whilst being weakly connected to the rest of the network, so that analysis can be applied to each subgraph independently. To this purpose, we focus on the so-called network motifs – small subgraphs up to 7 nodes. Motifs have been identified as "building blocks" that can be used to uncover key properties of networks[1].

Working on motifs presents several advantages: these are mesoscopic features of the networks, and are thus more meaningful than the atomistic features that are edges and nodes, and they can improve community detection algorithms – that classically minimise the number of edges to be cut between communities – by providing a higher-order representation of the network to partition[2,4]. A particular benefit is that the higher-order representation provides us with an undirected network whether or not the original one is directed or undirected. This enables one to apply tools specifically designed for undirected networks, for which there is a much better established body of work than for the directed case. Finally, since the search of motifs can be localised it is perfect for parallel computing.

We note that a focus on motifs for community detection has been done recently, and some of the initial research shows real promise [2,3,4] that worth to be expanded upon.

[1] R. Milo, S. Shen-Orr, S. Itzkovitz, N. Kashtan, D. Chklovskii, and U. Alon, (2002). "Network motifs: simple building blocks of complex networks", Science, vol. 298, no. 5594, pp. 824–827.

[2] A. Benson, D. Gleich, and J. Leskovec, (2016). "Higher-order organization of complex networks", Science, vol. 353, no. 6295, pp. 163–166.

[3] H. Yin, A. R. Benson, J. Leskovec, and D. F. Gleich, (2017). "Local higher-order graph clustering", in SIGKDD International Conference on Knowledge Discovery and Data Mining, pp. 555–564.

[4] C. Tsourakakis, J. Pachocki, and M. Mitzenmacher, (2017). «Scalable Motif-aware Graph Clustering», In the 26th International Conference on World Wide Web (WWW '17).

Lia Ying Li

Dr Li is a Royal Academy of Engineering Intelligence Community Postdoctoral Fellow. She is an expert in optical and quantum technologies, having worked with laser enabled devices for over a decade. After obtaining a first-class MSci degree in physics from Imperial College, she worked in R&D and project management at BAE Systems where she invented a method for creating microstructures in plastic optical fiber. Between 2012-2016 Lia completed a PhD developing optomechanical devices at UCL, with a focus on quantum sensing. In 2016 she was selected for the Nature/Entrepreneur First Innovation Forum in Quantum Technologies. After completing her PhD, she was awarded an EPSRC Postdoctoral Fellowship where she completed successful field-trials of a hand-fabricated optical accelerometer funded by Dstl. As part of her RAEng IC fellowship Lia is developing chip-scale versions of her optical accelerometer, extending the function into a gyroscope to create an all-optical inertial measurement unit that can act as an enabling device for quantum technologies.

Optomechanical Sensors: Rapid Prototyping for Navigation and Quantum Technologies

Optomechanical interactions, where mechanical motion is coupled to an optical field, can be amplified with optical resonances, yielding extraordinary displacement sensitivities beyond 10^(-18) m/Hz^(1/2). The ability to optomechanically detect motion 10,000x smaller than the width of an atom has enabled the first measurements of gravitational waves using kilometre long optical cavities. Now, academics around the world have begun a photonic revolution through developing optomechanical micro-optical-electro-mechanical systems (MOEMS) devices using sub-millimetre cavities. In this talk I will introduce a cavity optomechanics platform for motion sensing based on optical whispering gallery mode (WGM) resonances. I will describe the evolution of a WGM accelerometer from the laboratory to a hand-fabricated proof-of-concept prototype, and now, towards chip-scale fabrication. Our goal is to reach acceleration sensitivities below 100 ng/Hz^(1/2) (where g=9.81ms^(-2)) whilst ensuring low power operation, high linearity, and low drift. Transforming the accelerometer into a vibratory gyroscope with <0.01 degree/Hr^(1/2) sensitivity is also studied. Preliminary results from chip design, chip fabrication and chip-testing will be presented.

Yuzhang Li

Dr. Yuzhang Li is an Intelligence Community Postdoctoral Fellow at Stanford University with Professor Yi Cui. He received his bachelor's in Chemical Engineering from UC Berkeley and his Ph.D. in Materials Science and Engineering from Stanford University. As a graduate student, Yuzhang developed both engineering solutions and advanced characterization tools to make breakthroughs in next-generation batteries. Now, Yuzhang's research pursues innovations in energy and environmental technologies, which require advancements in both (1) fundamental characterization and (2) materials design. Yuzhang's research has been highlighted by news media (Forbes, Popular Mechanics, ABC7 Bay Area) and recognized with several awards (Dan Cubicciotti Award of the Electrochemical Society, Graduate Student Gold Award of the Materials Research Society). After his postdoc concludes, Yuzhang will be joining the department of chemical and biomolecular engineering at UCLA as an assistant professor.

Graphene Cage Design and Cryo-Electron Microscopy Characterization for High Energy Batteries

Lithium-ion (Li-ion) batteries with high energy density and long cycle life is critical for the widespread adoption of electrical vehicles and grid-scale energy storage. To meet the goal of three to four times state-of-the-art Li-ion capacity (1,350 – 1,800 mAh g^{-1}) combined with long cycle life (100,000 cycles) and safe operation, new chemistries are needed. Although both silicon (Si) and Li metal meet the required high energy capacity (~2,000 mAh g^{-1} and 3,860 mAh g^{-1}, respectively), intrinsic failure modes prevent their rechargeability and safe operation. In this talk, I highlight our initial accomplishments in two major thrusts that addresses both the fundamental and practical challenges of Si and Li metal. In the first thrust (engineering and design), I use my background in advanced nanomaterials design to engineer a graphene cage architecture (Y. Li, *Nature Energy* **1**, 15029, 2016) that can stabilize large-volume-change battery materials during operation. In the second thrust (fundamental understanding), I use my recently developed cryo-electron microscopy (cryo-EM) approach (Y. Li, *Science* **358**, 506, 2017) to study these reactive battery materials in their native environment with atomic resolution, which uncover new findings that guide future nanomaterials design. The synergy between these two thrusts will not only bring practical applications in the short-term, but also result in fundamental insights that will facilitate long-term solutions to stabilizing high-energy battery materials.

Nebila Lichiheb

Dr. Nebila Lichiheb is an Environmental Scientist at the Atmospheric Turbulence and Diffusion Division (ATDD) of the NOAA Air Resources Laboratory in Oak Ridge, TN. She began her fellowship as an IC Postdoctoral Research Associate in 2020 in order to optimize the use of existing federal data to improve the modeling of atmospheric pollutant dispersion in urban areas. The broader goal of her research is to refine estimations of air pollution and assess risks to human health and the environment. Her research interests include measurement and modeling of surface-atmosphere exchange of atmospheric gases and particles in agricultural, forest, coastal and urban ecosystems. Dr. Lichiheb is originally from Tunisia where she obtained an engineering degree in Agricultural Sciences from the National Agronomic Institute of Tunisia (INAT). She then moved to France to pursue her master's in Agroecology and Ph.D. in Environmental Sciences from AgroParisTech institute. She joined the staff at ATDD in 2016 as a National Research Council (NRC) Postdoctoral Research Associate studying ammonia fluxes in agricultural and forest ecosystems.

Improving the Prediction of Hazardous Material Dispersion in an Urban Environment

Nebila Lichiheb, LaToya Myles, William Pendergrass, Bruce Hicks, Torreon Creekmore

Atmospheric transport and deposition of hazardous materials in urban areas is increasingly under investigation due to the potential impact on human health and the environment. In response to health and safety concerns, several dispersion models have been developed to analyze and predict the transport and dispersion of hazardous contaminants. The models of interest usually rely on meteorological information obtained from the meteorological models of NOAA's National Weather Service (NWS). However, due to the complexity of the urban environment, NWS forecasts provide an inadequate basis for dispersion computation in urban areas. A dense meteorological network in Washington, DC, called DCNet, has been operated by NOAA since 2003 to support development of urban monitoring methodologies. The present proposal seeks to combine existing capabilities to improve the modeling of urban atmospheric dispersion.

The first step of this project was to describe and analyze data from DCNet research network in order to identify the key variables controlling dispersion model calculations. DCNet is a research program focused on the provision of real-time meteorological observations over Washington, DC. to support current numerical weather prediction models as well as provide the driving meteorological observations for atmospheric transport and dispersion models, such as the HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) model. The DCNet data are unique because they cover many years at many locations. They relate to a large city during all weather and climatic conditions, permitting an unparalleled description of the atmospheric flow behavior over a complex urban area largely unaffected by major terrain inconsistencies. Furthermore, contrary to the classical micrometeorological stations which are usually located at a major airport where conditions are considerably different from downtown, DCNet data are gathered within the urban core with enough sensors to describe all of the motions that are controlling local dispersion. It is a goal of programs like DCNet to provide a sound basis for improving descriptions of wind fields and for producing dispersion assessments that correctly account for the changing surface of the area.

The next step of the project will be to focus on the evaluation of the key variables controlling dispersion model calculations and to propose adjustments of these variables based on the comparison of the DCNet measurements and NWS model outputs. The proposed adjustments will then be implemented in the HYSPLIT dispersion model to improve the simulation of the atmospheric dispersion.

David Limbaugh

Dr. David Limbaugh is an Intelligence Community Postdoctoral Fellow working on applying to intelligence analysis lessons learned from the ways medicine handles data. His research is directed by Dr. Barry Smith at University at Buffalo and centers around ontology, referent tracking, and object-based production. David holds a Ph.D. from the University at Buffalo for a dissertation on the representation of possibility and necessity. It develops an account of how instances of dispositions explain the truth of statements like "Our satellite is capable of capturing that area" or "A collision is unavoidable".

The Cognitive Process Ontology and Modeling Autonomous Machines

By using layered models, where each layer is responsible only for a simple calculation before passing the task to the next layer, machine learning algorithms can perform extremely complex computations. However, as machines grow more complex, and as advances continue to be made in artificial intelligence, machine learning, and multi-agent systems, it becomes ever harder to *explain* the internal processes that guide a machine's behaviors. This creates a number of technical challenges, including: 1) structuring instructions for increasingly complex machines, 2) querying the data they process, and 3) understanding the provenance of that data.

The goal is to address these challenges in a way that ensures that critical information gets to the right users, at the right time, in the right format. We are seeking not explainable AI, which is still a hard problem. Rather, we seek an increase in explainability – and thus of controllability – of the sorts of things our machines and networks of machines are doing in the field of intelligence collection and analysis.

The Cognitive Process Ontology

The first step to increasing explainability is to develop a human-machine interoperable semantic structure. The Cognitive Process Ontology (CPO) is such a structure. CPO is an ontology developed to describe human cognition; and, it is also apt to describe by analogy the innerworkings and behaviors of autonomous machines. Most ontologies are used to tag data about outside-of-the-mind entities like tanks, aircraft parts, and behaviors of targets of interest. CPO extends ontology to the domain of cognition.

Using the Cognitive Process Ontology to Interact with Artificial Intelligence

We propose using CPO terms to tag machine states and machine actions — especially those that exhibit goal-oriented or autonomous behavior. In this way the same terms used when interacting with a human will be used also when commanding and controlling machines, for example when formulating and delivering operational objectives, querying data, assessing machine health.

When used in this way, CPO is connected logically to machine code expressions. This allows one to use CPO to meaningfully ask, for example "What hypothesis is currently guiding a machines behavior, and what is the expected knowledge gain from following that hypothesis?", and then expect an answer that represents the state of the machine that is structured in understandable cognitive terms. This lessens the human effort required to interact with a complex machine — and thus, increases efficiency and lessens the likelihood of errors — while also increasing the number of people in a decision chain who can understand machine interactions and the information produced by these interactions.

Christopher S. Linick

Department of Geological Sciences, Jackson School of Geosciences,
University of Texas Austin

Christopher S. Linick is a doctoral candidate in the Department of Geological Sciences at the University of Texas at Austin. He studies continental hydrology using the tools of geodesy, including terrestrial and space-based gravimetry, the Global Positioning System, and satellite radar. Linick has a B.S. in engineering physics from the University of California, Berkeley and an M.S.E. in aerospace engineering from the University of Texas at Austin. He received training in space mission operations as an intern at NASA's Jet Propulsion Laboratory in Pasadena, CA, and at the German Space Operations Center near Munich, Germany. He was a science team member for NASA's Gravity Recovery and Climate Experiment (GRACE), a space geodesy mission with extensive applications in hydrology and climate change. Before joining his current department, he spent six months as a guest researcher at the Technical University of Munich, studying methods of gravity field estimation for the Gravity field and steady-state Ocean Circulation Explorer (GOCE) space mission. Linick's current research focuses on estimating seasonal changes in snowpack and surface water from dense GPS observations of surface deformation, satellite gravity, and other data in the Sierra Nevada. In addition, Linick's research aims to reduce uncertainty of terrestrial gravimetry surveys. As part of this effort he maintains a superconducting gravimeter and suite of hydrologic sensors at McDonald Observatory in West Texas.

Sources of Small-Scale Gravity Variations at a Coastal Site

Christopher Linick, Clark R. Wilson, and Daniella Rempe

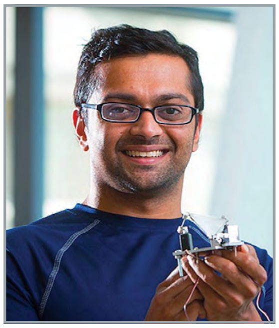
Absolute Gravity (AG) measurements conducted by NGA and other agencies provide important geodetic control at defense-related and other sites. AG surveys typically require several days of observations and are repeated episodically, with periods of months or years between measurement campaigns. Our project is designed to identify sources of small-scale (microGal-level) gravity variations that contaminate AG measurements during a campaign, and cause variations from one campaign to another. Potential sources include moving environmental masses, such as atmosphere and groundwater (and ocean at coastal sites), and seismic waves generated by wind, ocean waves, earthquakes, and human activities. An inland site in West Texas at the McDonald Observatory is instrumented with a superconducting gravimeter, geodetic quality GNSS receivers, and hydrologic sensors in preparation for a future AG survey to be performed by NGA. An NGA survey was conducted at this site in December 2018. The focus of this report is a February 2020 NGA AG survey at a coastal site near Corpus Christi Naval Air Station, at Texas A&M Corpus Christi. During this NGA campaign, environmental measurements using water level sensors and a broad band seismometer were made in order to improve the quality of the AG measurement.

Jeffrey Lopez

Jeffrey Lopez earned his Ph.D. in 2018 from Stanford University under the supervision of Prof. Zhenan Bao. He was awarded a NSF Graduate Research Fellowship and a NDSEG Fellowship to fund his graduate work, which focused on molecular design of new self-healing polymers and elastomers with novel mechanical properties for improving the stability of lithium ion batteries. Jeffrey is currently an Intelligence Community Postdoctoral Fellow at the Massachusetts Institute of Technology working with Prof. Yang Shao-Horn where he is studying fundamental mechanisms of electrochemical instability and ion transport in polymer electrolyte materials. Jeffrey has received multiple awards for his research including the ACS Eastman Chemical Student Award in Applied Polymer Science in 2018 and the AIChE Excellence in Graduate Polymer Research Award 1st Prize in 2016. Jeffrey was involved with the Stanford Polymer Collective as President from 2013-2016 supporting the polymer research community on Stanford's campus, and has worked with various programs at Stanford and MIT to promote improved access to higher education among students from underrepresented minority groups. Jeffrey will be joining the Chemical & Biological Engineering Department at Northwestern University as an Assistant Professor starting in September 2021.

Understanding and Design of Materials for High Energy Density Batteries

Lithium ion batteries have become the dominant form of energy storage used in consumer electronics and, recently, electric vehicles. However, high costs have prevented widespread deployment of lithium ion batteries for applications other than portable electronics, and the safety issues associated with liquid organic electrolytes remain to be addressed. In order to enable the greater utilization of electric vehicles, allow for grid scale energy storage, and meet the demands of new electronic applications, new materials for high energy density batteries must be developed. High capacity electrode materials like lithium metal have the potential to facilitate these technologies, but lithium metal electrodes are presently limited by significant side reactions, poor quality deposition, and the potential to form hazardous dendrites. Therefore, it is important to develop a clear understanding of the surface reactivity and growth behavior of the lithium metal at the interface with the electrolyte in order to enable stable long-term cycling.



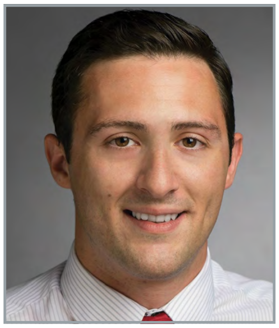
Manoranjan Majji

Dr. Manoranjan Majji is an assistant professor of Aerospace Engineering at Texas A&M University and is the director of the Land, Air and Space Robotics laboratory. He has a diverse background in several aspects of dynamics and control of aerospace vehicles with expertise spanning the whole spectrum of analysis, modeling, computations and experiments. In the areas of nonlinear estimation and system identification, he has made fundamental contributions documented in over 99 publications (including 28 journal articles). He is the recipient of the National Geospatial Intelligence Agency's new investigator award. He has also been recognized by the Milton Plesur Award for undergraduate teaching excellence. He has earned the best reviewer title for the Journal of Guidance, Control and Dynamics four times, and is a senior member of the AIAA. In addition to being a scholar, Dr. Majji has a great deal of engineering experience developing software systems and embedded systems from OEM products. Working with Systems and Processes Engineering Corporation (SPEC) at Austin, he authored several data processing algorithms for LADAR systems. He holds a provisional patent on a simultaneous location and mapping software suite along with John Junkins of Texas A&M University. His research has been funded by various agencies, including, NGA, NASA, AFOSR, ONR, DARPA, AFRL and the IC.

Geomagnetic Sensor Fusion for Alternative Positioning and Navigation

Sensor technologies and approaches for alternative positioning, navigation and timing are researched in this project.

Robust positioning and attitude estimation are important research problems to alleviate the increasing reliance of autonomous vehicles on the Global Positioning System (GPS). A research program at the confluence of modeling, analysis and field experiments is proposed to study mathematics and methods associated with estimation of position and heading of an autonomous system using magnetic field measurements of the Earth. Mathematical techniques that exploit recent advances in pattern analysis and machine intelligence to efficiently represent geomagnetic field signatures are presented. The use of these efficient representations for localizing the vehicle in a GPS-denied environment are elaborated. These measures can thus be utilized the guidance and control system of the platform to take appropriate actions to improve the resolution and accuracy of the positioning information. Numerical simulation results are shown to evaluate the approaches proposed in this research. Embedded computing implementations are utilized to evaluate the utility and efficiency of the alternative positioning and navigation approaches proposed in this work. Studies to trade-off algorithm performance with computational complexity, processing speed and memory needs are reported to aid in transitioning the proposed work to practice. Results from preliminary field experiments demonstrate the utility of the sensor fusion methods and experimental infrastructure being developed at Texas A&M to assess the utility of geomagnetic maps for alternative positioning and navigation.



Panos Markopoulos

Dr. Panos P. Markopoulos received the Ph.D. degree in Electrical Engineering from The State University of New York at Buffalo, Buffalo NY, USA, in 2015. Since 2015, he has been an Assistant Professor of Electrical Engineering with the Rochester Institute of Technology (RIT), Rochester NY, USA, where he directs the Machine Learning Optimization and Signal Processing Laboratory (MILOS LAB). His is also a core faculty of the RIT Center for Human-aware Artificial Intelligence (CHAI). In the Summers of 2018 and 2020, he served as Visiting Research Faculty at the U.S. Air Force Research Laboratory, in Rome NY. His research is in the areas of machine learning, signal processing, and data analysis, with a current focus on real-time and robust machine learning from multi-modal data. In these areas, he has co-authored more than 50 peer-reviewed journal and conference articles. Dr. Markopoulos's research has been supported with multiple grants from the U.S. National Science Foundation, US. Air Force Office of Scientific Research, U.S. Air Force Research Lab, the U.S. National Geospatial-Intelligence Agency, as well as industry partners. In Oct. 2019, he received the 2020 AFOSR Young Investigator Research Program (YIP) Award. He is a member of IEEE Signal Processing, Computer, and Communication Societies, with high service activity including, most recently, the organization of the IEEE International Workshop on Machine Learning for Signal Processing (IEEE MLSP 2019).

Improving CNNs Towards Real-Time Multi-Modal Object Detection in Remote Sensing Imagery

Deep-learning object detection methods that are designed for computer vision applications tend to under-perform when applied to remote sensing data. This is because, contrary to computer vision, in remote sensing targets can be very small, occupying only a few pixels in the entire image, and exhibit arbitrary perspective transformations. Detection performance can improve by fusing data from multiple remote sensing modalities, including RGB, IR, hyper-spectral, multi-spectral, synthetic aperture radar, and LiDAR, to name a few. In this talk, we present YOLOrs: a new convolutional neural network, specifically designed for real-time object detection in multi-modal remote sensing imagery. YOLOrs can detect objects at multiple scales, with smaller receptive fields to account for small targets, as well as predict target orientations. In addition, YOLOrs introduces a novel mid-level fusion architecture, that renders it applicable to multi-modal aerial imagery. Our experiments corroborate the efficiency of YOLOrs, compared to contemporary alternatives.

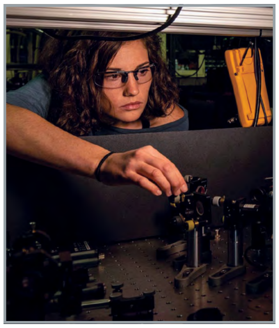
Claire Marvinney

Dr. Claire Marvinney is an Intelligence Community Postdoctoral Fellow working at Oak Ridge National Laboratory in the Quantum Information Science Group and is under the direction of Ben Lawrie. Here she is studying the phononic and electronic structures of quantum emitters at millikelvin temperatures. Claire received her Ph.D. from Vanderbilt University under the direction of Richard Haglund studying the photonic properties of zinc oxide nanostructures. During her Ph.D. Claire was chosen for the NSF East Asia and Pacific Summer Institute where she continued her research at Northeast Normal University. After graduation she worked with Josh Caldwell at Vanderbilt, studying the infrared optical properties of semiconductors. Through her research, she has expertise in quantum optics, dilution refrigerator operation, ultrafast photoluminescence spectroscopy, Raman spectroscopy, Fourier-transform infrared spectroscopy, 2D material transfer, scanning electron microscopy, and Lumerical FDTD simulations. Outside of research, Claire has been involved in the Oak Ride Postdoctoral Association, as Social Chair and member of the Research Symposium Committee, which just held a successful virtual symposium showcasing over 100 postdocs. She also participates in science outreach, volunteering with the ORNL Introduce Your Daughter to AI Day, and in the past with the Vanderbilt Chapter of the Materials Research Society, of which she was president for two years during her graduate studies.

Position-Dependent Response of Large-Area Superconducting Nanowire Single Photon Detectors

Superconducting nanowire single photon detectors (SNSPDs) are a state-of-the-art device for detecting single photons that have become increasingly relevant to quantum networking and quantum sensing because they have high-speeds, high-quantum-efficiencies, and low-dark-counts. Typical devices have a small active area, however, large-active-area devices are in demand for the emerging fields of single photon microscopy and free-space quantum communication. For a fiber-coupled, large-area SNSPD, we demonstrate that there is position sensitivity to the signal readout pulse, with slower rise times originating from the readout electronics end of the nanowire and faster rise times originating from the grounded end. These results, measured with a 33 GHz oscilloscope, are consistent with a simple model of microwave propagation along the length of the nanowire forming pulse echoes which vary with the origin position of the pulse. This effect is present for both bright counts and dark counts, which allows us to infer that dark counts arise uniformly across the length of the nanowire.

Currently, milliKelvin scanning confocal SNSPD experiments utilizing single and differential device readout have been developed in order to characterize the readout waveform with near-diffraction limited resolution. Additionally, the photon number resolution of large-area and small-area SNSPD devices will be explored in this system, in order to provide a microscopic understanding of the origins of photon number resolution within SNSPDs. Combining the preliminary measurements reported here with the planned microscopic device characterization will provide a potential new approach for filtering dark counts, for spectrally resolved single photon detection when diffraction gratings are incorporated with SNSPDs, and for resolving the number of simultaneous photons within a transmitted signal.



Katherine McCormick

Dr. Katherine McCormick is an IC Postdoctroal Fellow, she currently works as a physicist at the University of Washington in Seattle who studies applications of ultracold atomic physics to quantum simulation, chemistry, and sensing. She received her PhD in 2019 from the University of Colorado Boulder, where she studied how to harness the quantum mechanical motion of a single trapped ion to make extremely precise measurements of an electric field. She is excited to be applying her knowledge of quantum sensing to a new system in ultracold gases.

Toward a Sensitive, High-Resolution Atomic Magnetometer Based on Feshbach Resonances

It was recently proposed that the scattering properties of optically confined atoms might serve as a precise, high-resolution probe of the local magnetic field in the system [1]. In such a setup, one species of atom will traverse wave-guides produced by a two-dimensional optical lattice, scattering off of a second “impurity” species, as they travel. If the magnetic field is far from a Feshbach resonance between the two types of atoms, then the first atom will pass through unfettered. However, near a Feshbach resonance, the scattering properties are drastically altered, and this can be detected in the number of atoms that are reflected backward in the waveguides.

The Gupta lab at the University of Washington, having recently completed a comprehensive study of magnetic Feshbach resonances between Yb and Li [2], including their spin- and temperature-dependent behavior, is now well positioned to build such a magnetometer. I will describe ongoing efforts to this end, including integrating a three-dimensional optical lattice and stabilizing the magnetic field in our system, as well as theoretical work on predicting the shifts of the Feshbach resonances when confined to lower dimensions.

[1] Jachymski, K. et al. Single-atom transistor as a precise magnetic field sensor. PRL 120, 13401 (2018)

[2] A. Green, et al., arXiv:1912.04874 (2019)

Chris Metzler

Chris Metzler is an Intelligence Community Postdoctoral Research Fellow in the Stanford Computational Imaging Lab and will join the University Maryland Computer Science Department in January. Previously, he was an NSF Graduate Research Fellow, a DoD NDSEG Fellow, and a NASA Texas Space Grant Consortium Fellow in the Digital Signal Processing and Computational Imaging Labs at Rice University. His research develops data-driven solutions to challenging imaging problems.

Data-Driven Solutions to Challenging Imaging Problems

Machine learning (ML) and statistical signal processing (SSP) provide a powerful lens through which to develop and understand new imaging techniques. Together they allow one to abstract complex physical systems into manageable representations that can leverage new kinds of models and algorithms, such as deep learning.

In this talk, I will discuss our recent work where physical models were combined with SSP and ML to enable (1) data-driven system design for single-shot high-dynamic range imaging and (2) non-line-of-sight imaging through a door's keyhole using a time-resolved single-pixel detector.

David Messinger

Dr. Messinger received a Bachelors degree in Physics from Clarkson University and a Ph.D. in Physics from Rensselaer Polytechnic Institute. He has worked as an Analyst for XonTech Inc. and on the National Missile Defense Program for Northrop Grumman. Previously, he was an Intelligence Community Postdoctoral Research Fellow. He is currently a Professor, the Xerox Chair in Imaging Science, and Director of the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology where he previously was the Director of the Digital Imaging and Remote Sensing Laboratory. He is also an Associate Editor of the journal Optical Engineering, a Senior Member of SPIE, serves as the co-Chair of the SPIE conference “Algorithms, Technology, and Applications for Multispectral and Hyperspectral Imaging”, on the technical committee of the “Department of Energy Conference on Data Analysis (CODA)” and is a member of the USGIF Academic Advisory Board. He has published over 150 scholarly articles. His personal research focuses on projects related to remotely sensed spectral image exploitation using physics-based approaches and advanced mathematical techniques with applications to remote sensing problems, cultural heritage imaging, archeology, and disaster response.

Radiometrically Accurate Spatial Resolution Enhancement of Spectral Imagery for Improved Exploitation

The remote sensing community has a long history of developing methods to fuse the high spatial resolution information from panchromatic sensors with the spectrally diverse information, but generally of lower spatial resolution, from spectral sensors. This process is referred to as either panchromatic sharpening or spatial resolution enhancement. However, these methods have typically had as their primary motivation the creation of color imagery of high visual quality for visual interpretation. These methods do not in general seek to preserve the quantitative spectral information in the data and can sacrifice the radiometric fidelity of the spectral sensor. Several approaches exist and have been used to produce high resolution color imagery, however empirical evidence indicates that algorithmic performance is dependent on scene and sensor characteristics. This presentation will describe current work in the area of spectrally accurate spatial resolution enhancement of hyperspectral imagery, with a goal of ensuring good performance from spectral exploitation algorithms such as target detection. Research characterizing the performance of current best algorithms will demonstrate the issues when assessment is based on target detection performance. Additionally, a new algorithm based on a learning framework for MSI - HSI fusion will be presented. Finally we will discuss next steps and an experimental campaign designed specifically for this research project to be conducted this summer (hopefully). This research is sponsored by an NGA University Research Initiative.

Sara Mouradian

Dr. Sara Mouradian received her PhD in Electrical Engineering and Computer Science in the Quantum Photonics Laboratory at MIT working on scalable integrated architectures and diamond nanophotonics for quantum information processing with nitrogen vacancy centers in diamond. Her master's work was done in the Optical and Quantum Communications Group at MIT. There, she built the first demonstration of quantum illumination in the optical domain.

She is currently an Intelligence Community Postdoctoral Fellow at the University of California, Berkeley in the Ion Trap Group, working to build useful quantum sensors based on trapped ions. Her research interests include robust and scalable infrastructure for building the large-scale quantum systems that are necessary for the next generation of computing, communication, and sensing.

Trapped Ions as Useful Quantum Sensors

The record-high control and readout fidelities demonstrated with trapped ions have enabled high sensitivity quantum sensing of magnetic, electric, and light fields. Even so, the field of quantum sensing has been dominated by ensembles of atoms or solid state defects. However, the large number of sensors comes at a loss of control fidelity, which is not optimal in all scenarios. Many signals of interest are stochastic with a finite autocorrelation time and the signal may be intermittent, placing strict restrictions on the maximum integration time. We find that in such a scenario the achievable sensitivity scales strongly with the sensor's fidelity and the number of sub-unity sensors necessary to match the sensitivity of a single near-unity sensor explodes. Thus, high control fidelity is paramount for successful signal reconstruction. We demonstrate this protocol with a single trapped ion sensor with high control fidelity. Intentionally decreasing the control fidelity we see the expected strong scaling in the achievable frequency resolution.

Even with such a tailored use case, the utility of trapped-ion based sensors outside of a controlled laboratory environment is limited due to bulky, unstable optics, high power consumption, and systematic drifts in control lasers and electronics. Thus, we introduce an integrated photonics control platform for laser modulation and delivery. This will increase the stability of trapped ion sensors while simultaneously reducing the size and power consumption.

Karina Mrakovich

Dr. Karina Lorenz Mrakovcich is a Professor at the US Coast Guard Academy where she teaches Fisheries Biology, Fisheries Management and Atmospheric and Marine Sciences. She is the chair of the Education Committee for the Southern New England Chapter of the American Fisheries Society and a faculty fellow for the Goodwin-Niering Center for the Environment at the Connecticut College. Karina has a M.S. and a Ph.D. in Fisheries Science from Oregon State University. She was born and grew up in São Paulo, Brazil and studied Oceanography at the Universidade do Estado do Rio de Janeiro. Her research draws from fisheries and environmental sciences, maritime security, and scholarship of teaching and learning.

Exploring the Links Between Food Insecurity and Maritime Crime in Coastal West Africa

Karina Lorenz Mrakovcich and Christopher LaMonica, US Coast Guard Academy

West Africa's coastal communities continue to rely on fish as a primary source of protein and that is a problem: scientists and fisheries experts are now speaking of a complete collapse" of the Gulf of Guinea (GoG) region's fisheries sector this year, in 2020. The growing desperation among GoG fishers resulting from fish stock decline and concomitant income and food insecurity has led, as elsewhere, to opportunistic and increasingly coordinated maritime crimes in the form of piracy, drug smuggling, and human trafficking, to name a few. This study considers circumstances in Ghana and Senegal, specifically, where politicians and governing institutions remain focused on supporting the expansion of the fisheries sector, in return for political support, rather than contemplate other more sustainable policy options for improving food security. Illegal, Unregulated and Unreported (IUU) fishing is the norm among the region's small-scale canoe fishers, who openly and routinely engage in undocumented transshipment of fish, the illegal use of chemicals and dynamite to catch fish, and the use illegal gear. Trawling vessels are often owned by foreign interests who appear to comply with local laws by registering their vessels locally and hiring a 75% local crew. But dialogue with local authorities revealed to us that trawlers routinely violate fishing laws; fines, though (selectively) imposed, are usually "negotiated" for minimal payments, often via Alternative Dispute Resolution methods, due to the understood ineffectiveness of the local courts and other enforcement authorities. Local norms routinely include disregard and blatant avoidance of weak law enforcement authorities. Moreover, foreign interests are known to collude with local authorities to take full advantage of these circumstances in order to maximize their catch. This study spells out why West Africa's land-centered leadership needs to better appreciate the significance of the maritime domain to the region's economic well-being and concludes that there are fisheries management techniques that can offer effective ways to help replenish the region's fish stocks, thereby helping to reduce rates of opportunistic GoG maritime crime. Through interviews, field observations, quantitative and spatial analyses, we compare recent efforts of the governments of Ghana and Senegal to implement new fisheries management techniques, to include Closed Fishing Seasons, in a desperate attempt to find solutions to this crisis.

Andrea Nelson

Andrea Nelson is a second year optical sciences Ph.D. student at the University of Arizona working on optomechanical sensor fabrication and displacement interferometry in the Laboratory of Space Systems and Optomechanics (LASSO) under Dr. Felipe Guzman. She earned her B.A. in Linguistics and Japanese from the University of California, Davis in 2011 where her interest in astronomy and physics was solidified. She taught English in Japan for three years through the Japan Exchange and Teaching (JET) Program. She earned a B.S. in Physics from California State University Long Beach in 2019 where she worked on solution electrochemical experiments. She joined LASSO when she began the Ph.D. program at the University of Arizona in fall 2019.

Compact Quasi-Monolithic Heterodyne Laser Interferometers

Andrea Nelson, Hayden Wisniewski, Adam Hines, Logan Richardson, Felipe Guzman

High precision laser interferometers are highly advantageous for observing the displacement of a test mass with exquisite sensitivity in gravitational measurements. Applications in geodesy, gravitational physics, and geophysics require the advancement of gravitational acceleration sensing technologies and will largely benefit from more compact, portable and cost-effective systems. We are currently developing compact optomechanical gravimeters and gravity gradiometers of very high sensitivity that require displacement measurement sensitivities at levels of 10^{-14} m/√Hz in the sub-Hz frequency range and mQ-products above 100 kg. An integral component of our optomechanical technologies is the test mass laser-interferometric displacement sensor. We are developing compact quasi-monolithic heterodyne laser interferometers that provide a high common-mode rejection ratio to environmental disturbances using highly common optical paths. This allows for long-term noise reduction, as well as high sensitivity and stability. Breadboard prototypes operating in our laboratory at a wavelength of 632.8 nm in air have demonstrated displacement sensitivities at the picometer level with frequencies above 100 mHz. In-vacuum performance is expected to be significantly higher and measurement runs are currently underway. Moreover, we are redesigning these sensors to operate at near-infrared wavelengths of 1064 nm and 1550 nm where more stable and cost-effective laser units are available.

We will present our current designs and laboratory results, including our vision of how these devices will integrate into field-capable optomechanical gravimeters and gravity gradiometers.

Keng Tiong Ng

Dr. Keng Tiong (Kelvin) Ng is a UK Intelligence Community (IC) Postdoctoral Research Fellow funded by Royal Academy of Engineering and is currently working in the Emerging Chemical Contaminants Group at Imperial College London. Kelvin has a strong background in both analytical and organic chemistry. Before joining the UK IC fellowship programme, he undertook various industrial placements and held postdoctoral positions at Onyx Scientific UK, AstraZeneca UK, University of Sunderland and King's College London, with research encompassing a range of disciplines, including synthetic chemistry, analytical chemistry and ecotoxicology. For the last two years, he has been working within the Environmental Research Group, led by Dr Leon Barron and based at King's College London. During this time, he successfully developed a high-throughput LC-MS/MS method for the simultaneous detection of over 100 compounds, including pharmaceuticals, illicit drugs, metabolites and pesticides in freshwater invertebrates, municipal wastewater and river water, in under 5 minutes. The work has since been published in the Journal of Hazardous Materials, a high-ranking peer-reviewed journal. In October 2019, he then started his two-year UK IC fellowship in collaboration with the Centre for the Protection of National Infrastructure (CPNI). His research project is aimed at the identification of potential markers that are already present and/or can be added to explosive and chemical threat precursors, in order to tackle clandestine activity *via* wastewater analysis.

Identification of Illegal Threat Manufacturing Activity via Wastewater Markers

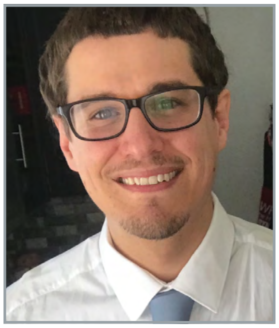
Given the global rise in terrorist activity as a result of the ease of acquiring cheap and simple household materials for illegal explosive and chemical production, early identification of the illicit manufacture of threat agents is critical for protection of public safety. Though there are many existing mechanisms available for threat detection, an alternative approach for monitoring illegal activity through the detection of the synthesised final threat compounds, as well as their precursors, stable transformation products and/or potential markers in sewer systems is proposed. This is expected to be a vital contribution to existing knowledge as several threat products and precursors are physically and/or chemically unstable and/or prone to evaporation, degradation and side reactions over time, leading to inaccurate end results and potential false negatives. The occurrence of illegal drugs, alcohol, medications and other toxicants in the wastewater network of a city is a well-established and documented means to understand community consumption patterns, lifestyle and health status. To date, however, this wastewater epidemiology has not yet been widely applied and extended to security threat agents. The aim of this research project is to develop new capabilities for identifying and monitoring a large number of explosives and chemical threats, as well as their markers, to indicate clandestine synthesis activity *via* wastewater analysis. Success in the research project will be built upon to set reliable baseline thresholds for explosive and chemical threat markers in London wastewater and, subsequently, extend these capabilities towards the localisation of threat material production activity. A comprehensive database of ingredients, impurities and additives present in the household commercial products that have been known to be used for explosive and chemical threat production will be compiled through literature searching and/or analytical measurement. Then, municipal wastewater will be screened to identify markers that can reliably be used to indicate synthetic activity of these threat agents. Ideally, marker candidates should be unique transformation products formed during illegal manufacturing, which can be reliably differentiated from those manufactured legitimately and are stable, non-volatile, inert and absent, or present at only a very low concentration, in the wastewater. Homemade explosive threats, particularly peroxides, nitrated sugars and inorganic explosives will be the predominant focus of the research, which will later be expanded to include precursors, mimics and stabilisers used in the synthesis of nerve agents.

Alvitta Ottley

Dr. Alvitta Ottley is an Assistant Professor in the Department of Computer Science & Engineering at Washington University in St. Louis, Missouri, USA. She also holds a courtesy appointment in the Department of Psychological and Brain Sciences. Her research uses interdisciplinary approaches to solve problems such as how best to display information for effective decision-making and how we can design human-in-the-loop visual analytics interfaces that are more attuned to the way people think. Dr. Ottley was the recipient of an NSF CRII Award in 2018 on the topic of using visualization to support medical decision-making. Her work has appeared in leading conferences and journals such as CHI, InfoVis, VAST, and TVCG.

The Role of Individual Differences in Moderating Complex Analytic Workflows

Developments in data visualization research have enabled visualization systems to achieve great general usability and application across a variety of domains. These advancements have improved not only people's understanding of data, but also the general understanding of people themselves, and how they interact with visualization systems. In particular, researchers have gradually come to recognize the deficiency of having one-size-fits-all visualization interfaces, and have shown that the effectiveness of a visualization tool depends on the experience, personality, and cognitive abilities of the user. This work has also demonstrated that these individual traits can have significant implications for tools that support reasoning and decision-making with data. However, most studies in this area to date have involved only short-duration tasks performed by lay users. In this talk, we will review the research perspectives, as well as the personality traits and cognitive abilities, visualizations, tasks, and measures investigated in the existing literature. We will then present a preliminary analysis of a series of exercises with 22 trained intelligence analysts that seeks to deepen our understanding of how individual differences modulate expert behavior in complex analysis tasks.



Christian Parkinson

Dr. Christian Parkinson is a postdoctoral research associate in the mathematics department at the University of Arizona, specializing in applied mathematics and data-driven modeling. Prior to this, he received his doctorate from UCLA where his research focused on applications of control theory and Hamilton-Jacobi equations to optimal path planning and deforestation modeling. More recently, he has worked on epidemic modeling, focusing on the effects of non-compliance with prevention measures and on the economic impact of quarantine. He lives in Tucson, Arizona with his wife, and in his free time, he enjoys watching movies, reading fiction and playing tennis.

Sparsity Models for Spatiotemporal Analysis and Modeling of Human Activity and Social Networks in a Geographic Context

Andrea Bertozzi, Bohan Chen, and Christian Parkinson

We will review two recent works on optimal path planning. (1) We address the problem of optimal path planning for a simple nonholonomic vehicle in the presence of obstacles. Most current approaches are either split hierarchically into global path planning and local collision avoidance, or neglect some of the ambient geometry by assuming the car is a point mass. We present a Hamilton-Jacobi formulation of the problem that resolves time-optimal paths and considers the geometry of the vehicle. (2) We address the problem of practical patrol strategies for environmental crime, in which the patrol density is considered as an important parameter.

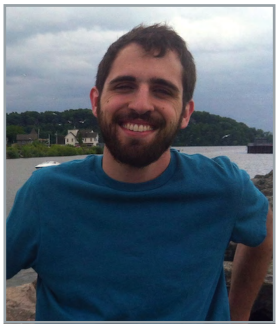
However, in actual situations, not all patrol strategies are realistic. This work defines a practical patrol strategy in terms of ways to send each group, the path each patrol group takes and the time arrangement of each group. We discuss methods that generate a patrol density function based on practical strategies and that find the nearest practical strategy to a certain patrol density.

Pencho Petrushev

Pencho Petrushev (PhD, Sofia University, Bulgaria) teaches mathematics at the University of South Carolina. Dr. Petrushev has authored one monograph (Cambridge University Press) and more than 100 research articles published in highly ranked journals such as Transactions of AMS, Proceedings of the London Mathematical Society, Journal of Functional Analysis. He is on the editorial boards of several prestigious mathematics journals: Foundations of Computational Mathematics, Constructive Approximation, Journal of Approximation Theory, SIAM Journal on Mathematical Analysis, Journal of Fourier Analysis and Applications, Transactions of Mathematics and Its Applications. His research interests are mainly in Approximation Theory, Harmonic Analysis, and their applications, including Geomagnetic and Geopotential field modeling, Data analysis, Image and signal processing.

Oblique Derivative Boundary Value Problem with Application to Geomagnetic Field Modeling

Potential fields are considered in the exterior of star-shaped compact sets in the three dimensional space (like the Earth). The focus is on the recovery of such fields given their intensity (length of gradient) on the boundary of the set. It is shown that this nonlinear problem is closely related to oblique derivative boundary value problems (ODBVP). A review of the literature on ODBVPs will be given. An algorithm for solving the ODBVP is developed for the exterior of an ellipsoid that involves ellipsoidal harmonics. The capability of the algorithm will be demonstrated in the simpler case of the ball. Targeted application of this research is to geomagnetic filed modeling as well as gravity filed modeling.



Robert Pettit

Dr. Robert Pettit received a B.S. in Physics from Allegheny College in Meadville, Pennsylvania in 2012, and completed his PhD in 2019 at the Institute of Optics at the University of Rochester in Rochester, NY. His doctoral work was supervised by Prof. Nick Vamivakas and focused on levitated optomechanical systems. He was awarded the OSA Emil Wolf Outstanding Student Paper prize as well as the Rochester Precision Optics prize for graduate research. He is currently an Intelligence Community Postdoctoral Fellow at the University of Maryland, where he is working in the laboratory of Prof. Edo Waks on microwave-to-optical quantum state transduction with semiconductor quantum dots.

Quantum Communication by Optical Fiber Links Using Quantum Dot Molecules

Advances in quantum information science have led to improvements in our fundamental understanding of quantum mechanics as well as technical progress in applications such as remote quantum sensing, secure quantum communication, and distributed quantum computing. However, the ultimate realization of these applications requires an ability to transfer quantum states over large distances, a task which remains a significant technical hurdle. This hurdle is especially challenging for superconducting qubits, which operate at microwave frequencies and are therefore limited by lossy microwave transmission lines. A leading approach to overcome this hurdle is to integrate quantum information platforms with optical fiber links to exploit low loss optical transmission. In this presentation I will discuss an approach to realize such a link using a pair of vertically stacked, self-assembled semiconductor quantum dots. Semiconductor quantum dots are known to have pristine optical properties, and pairs of these dots can form molecular spin states that are robust against electric and magnetic field noise. Quantum dot molecules also possess strong electric dipole moments and may therefore provide a direct means to couple with superconducting microwave cavities, providing a necessary quantum link between the optical and microwave frequency domains.

Dieter Pfoser

Dr. Dieter Pfoser received a PhD in computer science from Aalborg University, Denmark in 2000. He is currently a professor and chair, Dept. of Geography and GeoInformation Science at George Mason University. He teaches courses related to geospatial data management, Linked Data, Web application development using open-source software, and data-driven storytelling. His research interests include spatiotemporal data management, data mining for trajectory data, graph algorithms for dynamic networks, and user-generated geospatial content, e.g., map-matching and map construction algorithms. He has co-authored over 100 fully refereed papers, one book, edited five books and several journal issues, organized conferences, served on more than 40 program committees and on the editorial board of two journals. His research has been supported by NSF, DARPA, DHS and the European Commission.

Generation and Management of Crowdsourced Place Gazetteers

Traditional gazetteers and maps are artifacts of a geometry-driven view of the world, communicating primarily predefined locations and their coordinates, and lacking the meaning assigned to space by human activities, interactions, and perceptions. Although our research has initially focused on developing methods to extract platial content from Web content (social media, textual narratives), recent efforts have been towards analyzing movement patterns in urban areas. The study of urban mobility is a challenging task given the overall lack of individual-level mobility data and high acquisition cost of the existing commercial travel-diary data from cell phone or taxi trajectories. Although not representative of the entire population, social media data captures the sentiment of a significant portion of the population. Our focus is on revealing the urban spatial structure by exploring the linkage between geo-tagged tweets and transportation networks. The research objective of this work is extract meaningful movement information from geo-located tweets and understand human mobility patterns in urban areas. We analyze geo-tagged Twitter trajectories collected for the Washington DC metropolitan area and develop a heuristic algorithm to generate a movement network that summarizes human mobility for this area. To better comprehend the overall travel behavior and to discover the structure of the movement network we use the k-core decomposition method and extract a layered network structure capturing connections between places of varying importance and providing us with a better understanding of global vs. local connections. To assess the suitability of social media data for comprehending urban mobility patterns, we compare this social media derived movement network with movements generated from LODES data (Longitudinal Employer-Household Dynamics OD Employment Statistics) collected as part of the CENSUS LEHD program.

Mitchell Plyler

Mitchell Plyler is a second year PhD student in the Department of Computer Science at North Carolina State University (NCSU). Previously, he earned a BS in Aerospace Engineering from NCSU and a SM in Aeronautics and Astronautics from Massachusetts Institute of Technology (MIT) where he was a Draper Fellow. After MIT, he worked for Intelligent Automation Inc. supporting mostly SBIR/STTR projects.

Counterfactual Explanations for Text Classifiers

We present counterfactual explanations for text classifiers. In this context, a counterfactual is defined as an alternative version of an input document which would elicit the opposite class decision from the classifier. The counterfactuals can serve as an explanation for a single sample, showing how much or little needs to change in the source text to change the response of the classifier. We also show how aggregating these counterfactuals can illuminate the general behaviour of a classifier as it pertains to a dataset. We present results on a demonstrative multi-aspect beer review dataset, and more practical results on a dataset pertaining to influence campaigns during the 2016 U.S. presidential election.

Michelle Povinelli

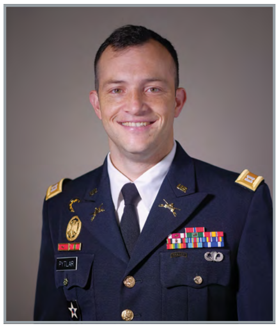
Dr. Michelle L. Povinelli is a Professor of Electrical Engineering and Physics at the University of Southern California. Her research area is nanophotonics, understanding how modifying the nanoscale structure of materials affects their optical properties at visible and infrared wavelengths. She is a recipient of the Presidential Early Career Award for Scientists and Engineers, the Army Young Investigator Award, and the NSF CAREER Award. She was a member of the 2018-19 Defense Science Study Group, an educational program for science and engineering professors sponsored by DARPA and run by IDA. She is currently the Director of the University of Southern California Intelligence Community Center for Academic Excellence, sponsored by a grant from ODNI. She holds a BA from University of Chicago, an MPhil from the University of Cambridge where she was a Churchill Scholar, and a PhD from MIT, all in Physics.

Designing Microstructured Materials with Tailored Thermal Emission

We are studying the relationship between material microstructure and thermal emissivity in order to design novel materials with customized emissive properties.

In past work, we have designed "self-adaptive" materials that change their broadband thermal emissivity to maintain a fixed temperature. We have also studied materials that support microphotonic resonances, electromagnetic modes that lead to narrowband thermal emission peaks. For static systems, resonances can be designed to create peaks in the emissivity spectrum at various wavelengths of interest. For dynamic systems, we can use thermal tuning to shift or erase certain spectral peaks. To achieve this functionality, our prototypical device design uses microscale gratings made of metal and a solid-state, phase-change material.

In future work, we plan to investigate strategies for electrical tuning of emissivity. We are particularly interested in how electrical tuning can be used to change the amplitude and angular distribution of thermal emission from materials. We will focus on III-V semiconductor materials that support microphotonic resonances. Our work aims to develop strategies to magnify the effects of tuning in the system, so as to maximize the total change in emissive properties.



Alexander Pytlar

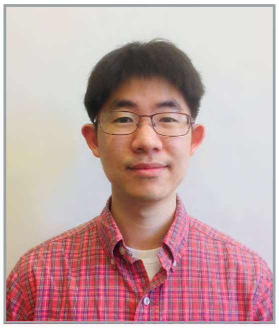
CPT Alexander Pytlar (MPA, School of International and Public Affairs at Columbia University) is currently an Instructor in the Geography and Environmental Engineering (GENE) Department at the United States Military Academy at West Point. CPT Pytlar began his career as an Armor officer and has served in both Tank and Cavalry units. To date, he has deployed in support of Operation Spartan Shield and Operation Enduring Freedom. Following his Company Command, CPT Pytlar was selected to join the GENE faculty and completed his MPA at Columbia SIPA, with a concentration in Energy and the Environment and a focus on urban environments. His capstone research developed a conceptual framework to better understand the stability and resilience of cities. He currently teaches an introductory course in physical geography and assists in the execution of USMA's Hacking 4 Defense course. CPT Pytlar's research interests include the examination of the intersection of energy, environment, and national security as well as the future of military operations in cities.

Understanding the Urban Environment: A New Framework for Urban Reslience and Stability

The primary objective of this research is to highlight the most important factors affecting the stability of current and future cities. The ultimate goal is the development of a generalized model that conceptualizes urban stability and resilience so decision makers can rapidly assess and understand the conditions of a city and apply resources to maintain or increase a city's stability. The study evaluates a city's stability through three dimensions – adaptive capacity, coping capacity, and expectancy benchmarks. It assesses these stability dimensions across eight criteria: Governance, Economics, Natural Environment, Energy, Technology and Communication, Culture, and Security. Two case studies are used to demonstrate how the framework can be applied to cities under stress or shock: Hurricane Sandy in New York City and The Umbrella Movement in Hong Kong. Future work will consist of developing data inputs to support quantitative scoring of the dimensions and criteria, with an opportunity to identify stability tipping points.

Global urbanization is occurring at an increasing rate, creating cities with unprecedented population density, size, scale, and population totals that were nearly unimaginable just a century ago. Cities are home to some of the most vulnerable systems that large proportions of the global population rely upon, such as water and sanitation limitations, as well as the site of new and increasingly critical factors such as enhanced internet-connectivity and profound electrical dependency. At some point, these new population centers will likely experience crises that demand outside involvement. The United States military is uniquely situated as well as expected to assist in these crises and respond to future conflicts.

As such, it is critical that planners have a framework that can be applied when evaluating urban environments from which they may draw reasonable conclusions regarding decision-making. Existing DoD frameworks (i.e. PMESII-PT and ASCOPE) for analyzing and understanding current city environments are ill-suited to assess and evaluate the upcoming urban stability issues cities will be facing in the twenty-first century and beyond. This study highlights important factors affecting the stability of future cities, acknowledges the inability to bypass, surround, or ignore them as part of a larger conflict, and emphasizes the growing importance of human dynamics and people's expectations regarding urban situations and contexts. Dense urban environments are the hubs of technological opportunities and complications, increasingly interconnected international relations, and other significant risks and opportunities that impact and threaten urban stability.



Albert Ryou

Dr. Albert Ryou is currently a postdoctoral researcher in Electrical and Computer Engineering Department at the University of Washington, Seattle, conducting research in nanophotonics and novel light-matter interactions with Professor Arka Majumdar. Dr. Ryou received his PhD in atomic, molecular, and optical physics at the University of Chicago and a BA in physics at the University of Pennsylvania. His main research interest is in exploring quantum many-body physics by engineering exotic environments with coupled nanophotonic cavities and quantum matter, as well as investigating strong nonlinear optical candidates for building neuromorphic photonics. He is a recipient of NDSEG Graduate Fellowship, IC Postdoctoral Research Fellowship, and the Mistletoe Research Fellowship. He has co-authored ~30 publications, which have been cited more than 250 times (Google Scholar). Outside of laboratory, Albert enjoys watching movies, traveling, and hiking throughout the Pacific Northwest.

Ultra-Low-Power Microwave-to-Optical Signal Transducers to Facilitate Deep Neural Net Operation

Controlling light-matter interactions is at the heart of numerous technologies from lasers and sensors to energy harvesting. It is also key to unlocking, for instance, quantum simulations of high-temperature superconductivity, and generation and storage of flying qubits for quantum computing. An attractive platform for engineering light-matter interactions is integrated nanophotonics. Rapid progress in large-scale electromagnetic design and nanofabrication now enables fabrication of microscopic optical resonators that can trap light both spatially and temporally. Embedding layered materials on the resonators can yield novel applications, including sensors, modulators, nonlinear switches, and exotic light sources.

Logan Richardson

Dr. Logan Richardson is a post-doctoral associate at the University of Arizona. Logan received his Ph.D. from the Leibniz University of Hannover in 2019. Immediately after obtaining his Ph.D., he began working under Dr. Felipe Guzman in Laboratory of Space Systems and Optomechanics (LASSO) group at The University of Arizona. Logan is interested in inertial measurements, which started when studying gravimetry with cold atom interferometers during his Ph.D. research and has continued to with studying inertial measurements using optomechanical sensors. Logan obtained his M.Sc. at The University of Arizona College of Optical Sciences, and his B.S. in physics from the same university. Logan was born in Orlando Florida USA.

Hybridizing High Bandwidth Optomechanical Accelerometers with Atom Interferometers for Improved Inertial Measurements

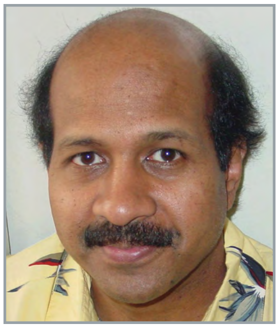
Authors: Logan Richardson, Adam Hines, Hayden Wisniewski, Andrea Nelson and Felipe Guzman

The field optomechanics has led to the development of compact inertially sensitive accelerometers. Such sensors employ laser interferometry for readout yielding extremely high displacement sensitivity and an insensitivity to external electro-magnetic fields. Such a device is promising for the applications of inertial navigation, accelerometry and gravimetry; however, being a relative accelerometer, these devices are prone to low-frequency signal drifts. This long-term drift can be addressed by periodically referencing to a long-term stable absolute acceleration reference.

In a similar development trajectory to inertially sensitive optomechanical sensors, the field of atom interferometry provides in field of long-term stable acceleration measurements. Atom interferometers provide many benefits over classical absolute accelerometers, such as the possibility to increase the sensitivity to acceleration without increasing the physical dimensions of the device, and virtually unlimited measurement repeatability without mechanical failure. However, absolute accelerometers, such as atom interferometers, suffer from limited bandwidth and are only capable of measuring signals with frequencies below their cycle frequency.

By taking a hybrid approach, we can combine high bandwidth inertially sensitive optomechanical sensors with the long-term stability provided by atom interferometers. Such a hybrid sensor yields a promising device that would be capable of measuring accelerations in a vibrationally noisy environment with a stability that fulfills the requirements of inertial navigation or airborne gravimetry.

Here we present the design of such a hybrid sensor. By combining an optmechanical sensor into the inertial reference of the atom interferometer, we effectively hybridize the two sensors providing maximal signal overlap between the two. The flexibility in design of the optmechanical sensor allows us to tailor the resonance and other mechanical properties to the mechanical transfer function of the atom interferometer, yielding an optimal hybrid sensor sensitivity.



Ashok Samal

Dr. Ashok Samal is a Professor in the Department of Computer Science and Engineering at the University of Nebraska-Lincoln, USA. He received a Bachelor of Technology from the Indian Institute of Technology, Kanpur, India, and a Ph.D. from the University of Utah, Salt Lake City, USA. His research interests include spatial data mining and computer vision, and he has published extensively in these areas.

Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model-and Data-Driven Approaches

Social unrest against government or state (in)actions fueled by socio-demographic or environmental factors is a great concern because of its potential impact on security and stability of any society at local, national, regional, and global scales. Of particular interest is the understanding and anticipating the cycles of contention for unrest that is challenging due to the ever-increasing volume, speed and variety of data (and noise) that is being generated, and the varying granularity of data (temporal, spatial and individual). Our *long-term goal* is to address these challenges by developing an *integrated model-driven and data-driven framework to anticipate social unrest events in a broad range of countries*. Model-driven approaches leverage human expertise, and social science-based theories to illuminate key factors—correlates and causes—underlying social unrest. Data-driven approaches exploit immediacy and comprehensiveness of data to discover patterns associated with unrest, help expand the models powered by algorithms, and inspire the model-driven social science efforts. Our goal is to examine the relationship of diverse thematic data that are increasingly becoming available in digital form including *Socio-demographic, Cultural, Environmental, Infrastructure, Geographic, Economic (SCEIGE) data*.

Currently we are 1) building our databases for SCEIGE data, unrest event data, and 5W analysis; 2) identifying and exploring SCEIGE factors that may behave as fuel or trigger for unrest events; 3) prototyping and evaluating an agent-based simulation framework for social unrest anticipation based on SCEIGE data; 4) developing a ground truth dataset for 5W analysis for the unrest events reported in news articles; and 5) establishing and validating novel algorithms that uses natural language processing and machine learning to accurately identify the location of unrest events.

So far we have 1) collected, curated, and analyzed data on various SCEIGE factors and proxies, including both news articles and existing datasets such as DesInventar, ACLED, ICEWS, GDELT, Census Data, CHIRPS data.; 2) performed exploratory and confirmatory factor analysis for various factors to discover their relationship with occurrence of protest; 3) developed a prototype multiagent simulation adopting a disease spread model to model how social unrest spreads spatially and over time; 4) extended our work on 5W analysis, in particular, to focus on improving our accuracy of extracting locations for social unrest events from newspaper articles; and 5) identified and will continue to evaluate the use of the Standardized Precipitation Index (SPI) as a proxy for agricultural productivity in the regions of interest. The current focus is on India. We will be expanding our scope to include Pakistan, Bangladesh, and Iraq in the next year.

Aswin Sankaranarayanan

Dr. Aswin Sankaranarayanan is an associate professor in the ECE department at CMU, where he is the PI of the Image Science Lab. His research interests are broadly in compressive sensing, computational photography, signal processing and machine vision. His doctoral research was in the University of Maryland where his dissertation won the distinguished dissertation award from the ECE department in 2009. Aswin is the recipient of the CVPR 2019 best paper award, the CIT Deanís Early Career Fellowship, the Spira Teaching award, the NSF CAREER award, the Eta Kappa Nu (CMU Chapter) Excellence in Teaching award, and the Herschel Rich Invention award from Rice University.

Optical Computing for Hyperspectral Imaging and Material Classification

Some of the most promising applications of hyperspectral imaging are hindered by the challenges in acquiring this. A typical hyperspectral image capture has to deal with the large data bandwidth due to the signal dimensionality as well as low signal-to-noise ratio due to lower light levels. We show that both of these challenges can be circumvented by adopting a holistic approach to sensing, where-in we measure the most relevant components of the hyperspectral image. In this talk, I will summarize recent work from my group that develops optical computing techniques to significantly reduce the number of measurements required to sense a hyperspectral image and its application in material classification. A key idea that emerges across multiple results is that careful adaptation of the sensing process to the scene under consideration can provide significant performance benefits in the form of higher light levels and fewer measurements.

Guillermo Sapiro

Dr. Guillermo Sapiro received his degrees from the Technion, Israel. After post-doc at MIT, he became Member of Technical Staff at HP Labs. He was the Distinguished McKnight University Professor and Vincentine Hermes-Luh Chair at the University of Minnesota. He is currently a James B. Duke Distinguished Professor, Duke University.

He works on differential geometry and geometric PDEs, learning theory, network analysis, theory and applications in computer vision, computer graphics, medical imaging, and image analysis. He has co-authored over 450 papers and a book, and transferred numerous technologies to private companies and to government agencies.

He was awarded the Rothschild Fellowship for Post-Doctoral Studies in 1993, the ONR Young Investigator Award in 1998, the Presidential Early Career Awards for Scientist and Engineers in 1998, the NSF Career Award in 1999. He delivered the first Science Lecture at the Abel Prize, 2009, and is Plenary Speaker for SIAM Image Sciences 2010 and SIAM Annual Meeting 2018. He was also awarded the National Security Science and Engineering Faculty Fellowship and twice the Test-of-Time Award, for one of the most cited papers in computer vision and again for one of the most cited papers in machine learning. He is a SIAM and an IEEE Fellow, member of the American Academy of Arts and Sciences, and founding Editor-in-Chief of the SIAM Journal on Imaging Sciences.

Learning Privacy and Do-No-Unnecessary-Harm Fairness

In the first part of the presentation, we discuss our recent work on privacy. Data collection and sharing are pervasive aspects of modern society. This process can either be voluntary, as in the case of a person taking a facial image to unlock his/her phone, or incidental, such as traffic cameras collecting videos on pedestrians. An undesirable side effect of these processes is that shared data can carry information about attributes that users might consider as sensitive, even when such information is of limited use for the task. It is therefore desirable for both data collectors and users to design procedures that minimize sensitive information leakage. Balancing the competing objectives of providing meaningful individualized service levels and inference while obfuscating sensitive information is still an open problem. In this work, we take an information theoretic approach that is implemented as an unconstrained adversarial game between Deep Neural Networks in a principled, data-driven manner. This approach enables us to learn domain-preserving stochastic transformations that maintain performance on existing algorithms while minimizing sensitive information leakage.

In the second part of the talk we will briefly address the problem of fairness. Common fairness definitions in machine learning focus on balancing various notions of disparity and utility. In we study fairness in the context of risk disparity among sub-populations. We introduce the framework of Pareto-optimal fairness, where the goal of reducing risk disparity gaps is secondary only to the principle of not doing unnecessary harm, a concept that is especially applicable to high-stakes domains such as healthcare. We provide analysis and methodology to obtain maximally-fair no-harm classifiers on finite datasets. We argue that even in domains where fairness at cost is required, no-harm fairness can prove to be the optimal first step. This same methodology can also be applied to any unbalanced classification task, where we want to dynamically equalize the misclassification risks across outcomes without degrading overall performance any more than strictly necessary. We test the proposed methodology on real case-studies of predicting income, ICU patient mortality, classifying skin lesions from images, and assessing credit risk, demonstrating how the proposed framework compares favorably to other traditional approaches.

John Serafini

Dr. John Serafini is an IC Postdoctoral Research Fellow in Dr. Stefan Preble's group at the Rochester Institute of Technology. His research focus is centered around the design and testing of quantum nanophotonic devices for the purposes of quantum information processing and sensing. He received his doctorate in physics from the University of Rochester under the guidance of Roman Sobolewski investigating high speed optoelectronic devices based on II-VI semiconductor materials.

A Compact Configuration for Two-Photon Interference to Support Quantum Computing

Quantum information science aims to revolutionize existing methods for measuring and manipulating data by utilizing the unique features of nonclassical physical phenomena like entanglement and superposition. There are a number of physical platforms conducive to processing quantum information, however, photons are uniquely qualified for room temperature, high stability, real-world quantum information technologies. This vision is realized through photonics by integrating photonic circuits on a silicon chip with the help of standard CMOS techniques to develop scalable building blocks based on ring resonators, directional couplers and phase shifters that dramatically reduce the footprint of the circuit to a few mm^2 and reduce the power requirements - on the order of mW - all while enabling novel functionality. In this presentation we will present results of a new, more compact configuration for a two-photon interference experiment that is capable of high visibility and also tunable. In addition, we will demonstrate a more efficient, low power phase shifter design for performing unitary transformations.

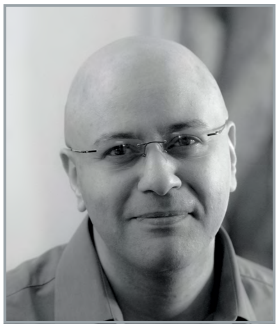
Shawn Serbin

Dr. Serbin's research focuses on the use remote sensing data, land-surface and radiative transfer modeling, as well as in-situ observations and experimentation to study mass and energy exchanges between terrestrial ecosystems and the atmosphere, land-atmosphere interactions, and quantify seasonal to long-term vegetation dynamics. He uses a variety of multi-scale passive optical, thermal, and active lidar data to map plant functional, structural and biophysical properties, simulate vegetation canopies, inform process models, and test model predictions.

Plant Spies: Using Foliar Messages to Remotely Detect Tunneling

Co-authors: Jeremiah A. Anderson, Kenneth L. Davidson, Andrew McMahon, Alistair Rogers

A DARPA seedling project was recently completed that aimed to identify plant responses to simulated tunneling and link tunneling responsive signals to remote sensing data. The work provided proof of concept that tunneling could be detected through remote sensing of the signals in plant leaves that communicate the stress associated with tunneling. We will present the results from this project, including the primary responses observed in plants and remote sensing data, our prototype detection efforts, and what we believe are the critical next steps to advance the field. The DARPA project is one of several efforts within our group that seeks to link plant form and function to remote sensing and we will highlight other advances in this area to illustrate how the combination of plant physiology and remote sensing can be used to monitor vegetation, inform models, and provide insight into food security.



Joseph A.E Shaheen

Dr. Joseph Shaheen is an Intelligence Community Postdoc Fellow (ODNI/NCTC) co-located with the faculty of the Department of Computational and Data Sciences at George Mason University. Since his first day of university training at age 15 and having earned his undergraduate degree in Engineering:Physics at age 19, his 15 years of industry experience has been diverse, ranging from industrial engineering to people analytics.

Dr. Shaheen earned his doctorate in Computational Social Science from GMU with a dissertation on economic policy and population-scale data analysis of Internal Revenue Service records under the guidance of Professor Rob Axtell's research group.

A life-long scholar, Joe has received training from academic leaders in Social Network Analysis and has been recognized as an honorary Links Center Fellow in 2015 and by GMU's Teaching Excellence award in 5 consecutive iterations. He has appeared on CNN HLN, FOX NEWS, NBC News, Entrepreneur Magazine and has been invited to participate in the 2020 (postponed to 2021) Heidelberg Laureate Forum (Heidelberg, Germany) where he will spend time with fellow scholars of the mathematical and computer sciences as well as Fields Medal, Abel Prize, Turing Award, and Nevanlinna prize winners.

Towards a Principled, Computational and Risk-Based Perspective in Dark Networks

In the domain of utilizing network data to ensure safety and national security, the paradigm of Dark Networks offers a systemic approach to identifying 'nodes of interest' in social networks. This paradigm is primarily based on the well-developed concepts of Social Network Analysis, but relies heavily on heuristic approaches that are often unprincipled (though powerful) from a statistical perspective. Recent advances in Network Science as well as greater availability of computational resources allow for more cautious approaches designed for risk-considered target policy-making.

This talk, highlighting our approach, will describe the use of simple graph-preserving sampling methods combined with the adoption of an information-theoretic perspective to social network analysis. Our mathematical grounding uses conceptions of graph divergence and to some extent, distance. Additionally, we will remain true to the structural perspective of social networks though it is trivial to expand to non-structural viewpoints. In general, we will discuss the strengths and weaknesses of the current paradigm and provide-what we will argue to be-a more sensible approach to targeting in line with known scientific theory.

Following on our methodological tutorial, we will propose the re-adoption of the Dark Networks paradigm as a targeting approach based on a risk management strategy rather than a definitive causal tool in intelligence collection and person of interest identification. This proposal provides for even greater flexibility in the use of this powerful tool-set.

Given time, we will show (or share slides) how our approach integrates well with classical notions of regular and structural equivalence, key players, and component division/fracture–all of which are in common use by the Intelligence Community for various applications.

Our talk is amenable to practitioners and enthusiasts of network analysis and aims to mix a discussion of classical theories with new trends in a thought-provoking application environment, but it is surely intended for a general IC, defense and security audience. For questions about this talk, please contact jshaheen@gmu.edu

Shashi Shekhar

Dr. Shashi Shekhar is a McKnight Distinguished University Professor at the University of Minnesota (Computer Science faculty). For contributions to geographic information systems (GIS), spatial databases, and spatial data mining, he was elected an IEEE Fellow as well as an AAAS Fellow and received the IEEE-CS Technical Achievement Award and the UCGIS Education Award. He has a distinguished academic record that includes 300+ refereed papers, a popular textbook on Spatial Databases (Prentice Hall, 2003), an authoritative Encyclopedia of GIS (Springer, 2nd Ed. 2017), and a spatial computing (MIT Press, 2020) book for a broad audience. Dr. Shashi is serving as a member of Computing Research Association (CRA) Board, and as a co-Editor-in-Chief of Geo- Informatica: An International Journal on Advances in Computer Sciences for GIS (Springer). Earlier, he served as the president of the University Consortium for GIS, and a member of the CRA Computing Community Consortium Council (2012- 15), and multiple National Academies' committees including Models of the World for USDOD-NGA (2015), Future Workforce for Geospatial Intelligence (2011) and Priorities for GEOINT Research (2004-2005).

Identifying Aberration Patterns in Multi-attribute Trajectory Data with Gaps

We propose to investigate spatial data science approaches for Identifying Aberration Patterns in Multi-attribute Trajectory Data with Gaps (IAP-MTD). Example multi-attribute trajectory data (MTD) includes maritime MTD recording ship attributes (e.g., draught, rate of turn) and vehicle MTD recording on-board diagnostic attributes (e.g., emission). An aberration pattern represents a significant deviation from expected values. Identifying such aberration patterns can help improve maritime security and prevent illicit activities (e.g., illegal fishing, illegal oil transfer to violate United Nations sanctions) where the involved objects may hide their movement by deliberately not reporting their locations. The challenges of this problem arise from the complexity of modeling gaps and a large amount of data. Existing works on trajectory mining focus on bare-bone trajectory data and consider only location-time information. In addition, they interpolate the gaps and ignore the many possibilities between consecutive reported locations. To overcome the limitations in the literature, we propose a three-phase approach. First, we propose a novel frustum-chain model that represents multi-attribute trajectory data with gaps as well as the position measurement error of reported locations. Second, we propose query methods to efficiently discover aberration patterns with known spatiotemporal signatures. Third, we propose data mining approaches to discover aberration patterns without known spatiotemporal signatures. Both theoretical and experimental methodologies including proofs, complexity analysis, and experiments with synthetic as well as real datasets (e.g., MarineCadastre) will be used to evaluate the computational efficiency of the proposed methods. Furthermore, case studies will be used to evaluate the effectiveness of proposed methods.

Martin Smyth

Dr. Martin Smyth is a visiting scholar at the Institute for Advanced Computational Science, Stony Brook University, and a visiting scientist in the Research Directorate at National Geospatial-Intelligence Agency (NGA). Since 2018, Dr. Smyth has worked with research mentor Dr. Michael Egan to advance the knowledge-frontier of temporal dynamics in global social media data. Their transdisciplinary research applies insights from network science, mechanical engineering and political economy to understand patterns in activity on social media platforms, as expressed in the content generated by millions of social media users. In 2019, they assembled an 'A-team' of expert researchers to explore the latent cause of an observed pattern in social media activity during the emergence of *en masse* political movements. They are excited to return to ICARS (virtually) this year to share the latest findings of their work together.

Information Processing on Social Media Networks as Emergent Collective Intelligence

Martin Smyth, Institute for Advanced Computational Science, Stony Brook University, State University of New York
Cody Buntain, Department of Informatics, Ying Wu College of Computing, New Jersey Institute of Technology
Debra Dwyer, Department of Economics, Farmingdale State College, State University of New York
Joseph Finn, Department of Electrical & Computer Engineering, Carnegie Mellon University
Joshua Garland, Santa Fe Institute
Jason Jones, Department of Sociology, Stony Brook University, State University of New York
Michael Egan, National Aeronautics and Space Administration

This NGA Research project looks to simulate the dynamics of information-behavioral synchronization on social media service platforms. While our research is focused on the emergence of mass-mobilization movements against authoritarian governments, our model dynamics are agnostic as to a particular application domain. Rather, our model simply describes the mechanism by which a network of individuals computes the flow of information across itself, thereby manifesting "collective intelligence" (Pentland 2006). In his breakthrough paper "Collective Cognition in Animal Groups," Couzin observes that "important commonalities exist with the understanding of neuronal processes," and that "much could be learned by considering collective animal behavior in the framework of cognitive science" (Couzin 2009). Per an analogy drawn by Hawking (Swartz 2014), information processing on social media platforms may bear similarity to the processing of information by neurons in the brain. We anticipate that exploring similarities in these dynamics may yield insights into the operation of both social and neuronal systems.

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Leen-Kiat Soh

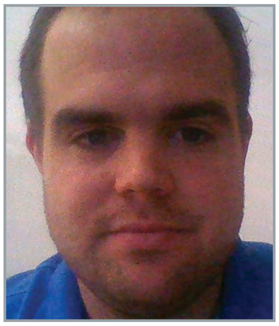
Dr. Leen-Kiat Soh is a Professor at Department of the Computer Science and Engineering with the University of Nebraska. His research interests are in multiagent systems, modeling, and simulation, computer science education, and intelligent data analysis. He has developed intelligent systems to improve teaching and learning, to support online collaboration, and to facilitate adaptive decision making. He has also modeled smart grids, human learning, and social unrest to better investigate emergent behaviors. Moreover, he has applied his research to survey informatics, image understanding, and learner analytics. He has published more than 250 journal, conference, and workshop papers in these areas. He is a Co-PI in an NGA-funded project called Social Unrest Reconnaissance Gazetteer and Explorer (SURGE). He is also the director of the Intelligent Agents and Multiagent Systems (IAMAS) research laboratory at the University of Nebraska. Dr. Soh has organized several technical workshops and served on numerous program and organizing committees of international conferences, such as SIGCSE, ITiCSE, ICER, AAMAS, IJCAI, and AAAI. Dr. Soh's research has been funded primarily by the NSF, NEH, IMLS, and NGA.

Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model-and Data-Driven Approaches

Social unrest against government or state (in)actions fueled by socio-demographic or environmental factors is a great concern because of its potential impact on security and stability of any society at local, national, regional, and global scales. Of particular interest is the understanding and anticipating the cycles of contention for unrest that is challenging due to the ever-increasing volume, speed and variety of data (and noise) that is being generated, and the varying granularity of data (temporal, spatial and individual). Our *long-term goal* is to address these challenges by developing an *integrated model-driven and data-driven framework to anticipate social unrest events in a broad range of countries*. Model-driven approaches leverage human expertise, and social science-based theories to illuminate key factors—correlates and causes—underlying social unrest. Data-driven approaches exploit immediacy and comprehensiveness of data to discover patterns associated with unrest, help expand the models powered by algorithms, and inspire the model-driven social science efforts. Our goal is to examine the relationship of diverse thematic data that are increasingly becoming available in digital form including *Socio-demographic, Cultural, Environmental, Infrastructure, Geographic, Economic (SCEIGE) data*.

Currently we are 1) building our databases for SCEIGE data, unrest event data, and 5W analysis; 2) identifying and exploring SCEIGE factors that may behave as fuel or trigger for unrest events; 3) prototyping and evaluating an agent-based simulation framework for social unrest anticipation based on SCEIGE data; 4) developing a ground truth dataset for 5W analysis for the unrest events reported in news articles; and 5) establishing and validating novel algorithms that uses natural language processing and machine learning to accurately identify the location of unrest events.

So far we have 1) collected, curated, and analyzed data on various SCEIGE factors and proxies, including both news articles and existing datasets such as DesInventar, ACLED, ICEWS, GDELT, Census Data, CHIRPS data.; 2) performed exploratory and confirmatory factor analysis for various factors to discover their relationship with occurrence of protest; 3) developed a prototype multiagent simulation adopting a disease spread model to model how social unrest spreads spatially and over time; 4) extended our work on 5W analysis, in particular, to focus on improving our accuracy of extracting locations for social unrest events from newspaper articles; and 5) identified and will continue to evaluate the use of the Standardized Precipitation Index (SPI) as a proxy for agricultural productivity in the regions of interest. The current focus is on India. We will be expanding our scope to include Pakistan, Bangladesh, and Iraq in the next year.



Steven Spiegel

Steven Spiegel is a Visiting Scientist working in the research branch at the National Geospatial-Intelligence Agency (NGA). His research focuses on point cloud collection, processing, and classification. These point cloud collections include Electro-Optical (EO) and LiDAR data. Previously, Steven received a master's degree in Geographic Information Sciences from Saint Louis University and an undergraduate degree in mathematics from Truman State University.

LiDAR Classification using Synthetic Data

3D object recognition is one of the most popular areas of study in computer vision. Many of the more recent algorithms focus on indoor point clouds, classifying 3D geometric objects, and segmenting outdoor 3D scenes. One of the challenges to the classification pipeline is finding adequate and accurate training data. Hence, this paper seeks to evaluate the accuracy synthetically generated dataset called SynthCity tested on two mobile laser scan datasets. Varying levels of noise were applied to the training data to reflect varying levels of noise in different scanners. The chosen deep learning algorithm used was Kernel Point Convolution (KPConv), a convolutional neural network that uses kernel points in Euclidean space for convolution weights.

Cedric Spire

Dr. Cedric Spire is an UK IC Postdoctoral Fellow (RAEng UK IC 2019) at Brunel University London, working on the development of automated anomaly detection and correction methods for diverse data types. This research is done in collaboration with a UK public sector organization. Dr. Spire has a background in Physics (BSc) and Statistics (MSc) which led him to strive to develop novel statistical and machine learning methods to tackle real-world problems. Dr. Spire's PhD involved the development of a new Bayesian methodology to perform learning in the absence of training data, with a direct application to astrophysical data.

Automated Error Detection & Repair in Structured Databases

As the quantity of data available to us has been vastly increasing over the last two decades, so did the time and resources taken to process and analyse this ocean of information. There is therefore a strong need to perform pre-processing operations, such as data cleaning, in a more efficient and automated way. Cleaning data is one of the first steps in any statistical machine learning pipeline and can take an important amount of time. Common tasks such as outlier detection, entity resolution (duplicates identification and removal), missing data resolution and mis-spells correction, can be extremely time-consuming to manually handle even for moderately large datasets. Additionally, the tediousness of that kind of tasks make it error prone. The motivations are thus twofold: 1) Save time for the analysts, and 2) improve the quality of the data. The benefits of an automated error-detection and correction system would ultimately allow the analysts to *use* the data on more meaningful tasks, rather than *struggle* with it. By the same token, building a facility (such as a GUI) from which all databases could be displayed, searched through and cleaned easily without having to go through the original file itself, would make the cleaning task much easier and faster. Simple data visualisation tools on numerical data can also be used to observe any trend or outlier in the data. In this presentation, I introduce my preliminary work through a developed GUI that can perform search, edit and cleaning operations as well as visualisation tasks on tabulated databases.

Michael Jasser-Stone

Dr. Michael Jasser-Stone is a third year IC Postdoctoral Research Fellow at the University of Florida in Gainesville, Florida. His research area is on direct shear failure modes of Ultra-High Performance Concrete under dynamic loads. He attended Florida International University for his BSCE where he focused on structures and worked on curtain wall anchorage systems. He began his Masters in Civil Engineering at the University of Florida and continued with his Ph.D., studying failure behavior and energy flow of Ultra-High Performance Concrete beams and cylinders under impact loading with high energy drop hammers. He also assisted with developing equipment for dynamic penetration testing of soils inside centrifuges. His current research focuses on numerical assessment and modeling of direct shear failure mechanisms of UHPC using frequency analysis and energy transfer mechanisms. His other research interests include analyzing structural response to impulsive loads, numerical simulations using finite and discrete element methods, and development of numerical tools for structural engineering.

Frequency and Energy Methods in Direct Shear Behavior of Ultra-High Performance Concrete

Direct shear failure in concrete structures is both sudden and catastrophic. The failure mode is characterized by complete failure of the structural system along a plane that is typically located at either a geometric or a load discontinuity. It is typically induced by severe impulsive loads such as blast loading or direct induced ground shock, and as such occurs rapidly and before other structural resistance mechanisms can be activated. New materials for protective structures include ultra-high performance concrete (UHPC) and ultra-high performance fiber reinforced concrete (UHPFRC). These materials are carefully designed to have extremely high compressive strength capacity, higher tensile capacity, and ductility due to use of refined aggregates, admixtures, and optional inclusion of large amounts of steel fibers for UHPFRC.

Current models for structural direct shear behavior are based on empirical testing of “push-off” specimens and was developed based on experiments using normal-strength (NSC) and high-strength concretes (HSC) with and without fibers. These models relate the shear-stress to the total slip using empirical formulas derived from test specimens. Recent of NSC, UHPC, and UHPFRC push-off specimens have shown correlations between structural and loading frequency and the resulting direct-shear response. Results from this research have shown a relationship between structural response and frequency domain assessment. Additionally, energy input and energy input rate are factors in structural response modes. Current research is focused on analysis using a mix of finite element (FEM) and discrete element (DEM) models. These results can provide a basis for analysis of direct shear using energy methods instead of empirical models. These energy methods can be used to develop fast-running tools to predict risk and vulnerability of structures to direct-shear failure using methods similar to current pressure-impulse (P-I) diagrams.

Yun Tao

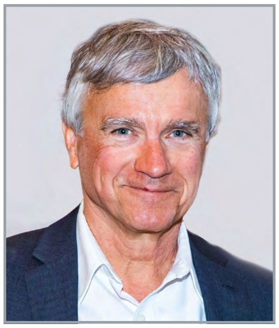
Dr. Yun Tao is an Intelligence Community Postdoctoral Research Fellow working at the interface of behavioral, disease, and population biology using mixed quantitative approaches to investigate the transient, hidden dynamics in complex biological systems. He has developed mathematical and computational frameworks for modeling large-scale ecological and movement patterns, predicting risks of zoonotic outbreaks, and informing vaccination strategies in advance of epidemics. Yun Tao completed his PhD in Ecology at the University of California, Davis, subsequently worked closely with the University of Helsinki and EcoHealth Alliance, followed by postdoctoral appointments at the Center for Infectious Disease Dynamics at Penn State University and the University of California, Riverside. He is the recipient of NSF Graduate Research Fellowship, NSF Research Opportunities Worldwide Fellowship, EcoHealthNet Research Exchange Fellowship, and the Lotka-Volterra Award from the Ecological Society of America.

Transient Dynamics in Outbreak Management and a Retrospective Analysis of the 2001 FMDV Epidemic in United Kingdom

Y. Tao, J. Hite, N. Bharti, D. Earn, W. Probert, K. Shea, M. Tildesley, M. Ferrari, K. Lafferty

Analyses of transient dynamics are critical to our understanding of infectious diseases. Identifying, elucidating, and predicting transients – from within-host to metapopulation level patterns – can play an important role in combating ongoing epidemics (such as the current COVID-19 pandemic) and in mitigating the risk of future outbreaks. We argue that greater model emphases on transient processes observed specifically during outbreak responses will enable more timely evaluations of wildlife, livestock, and human diseases, leading to enhanced clinical practices, surveillance efforts, and management strategies. In part one, we briefly explore the contributions of such transient analysis spanning the fields of epidemiology, disease ecology, medical sciences, and parasitology.

Achieving rapid responses to premises targeted for interventions is vital to the provision of strong biosecurity measures and the overall success of animal disease management programs. However, highly variable response delay has been a recurrent problem in past cases of livestock epidemics when mass depopulation was put into effect. In many models, the scheduling of control actions on individual farm was nevertheless assumed to closely mirror a fixed, idealized timeframe without reflecting the disconnect between policy advice and management reality caused by common logistical constraints. In part two, using survival analysis, we examined the 2001 UK Foot-and-mouth Disease Virus (FMDV) management timeline to reveal factors that impeded timely culling and disposal activities. We subsequently applied the Warwick model to evaluate how increasingly accurate model representations of the transient response process can influence national outbreak predictions. We identified farm size and number of premises in the response queue as key contributors to local response delays. Our results further suggest that simple model descriptions of outbreak management, e.g. policy-conforming responses, may grossly underestimate outbreak severity and its long-term consequences. Our results underline the value of basing expectations of response efficiency on transient, premises-specific logistical constraints. Including such operational context in management models can help improve real-time forecasts and inform decision-making.



Charles Toth

Dr. Charles K. Toth is a Research Professor in the Department of Civil, Environmental and Geodetic Engineering, The Ohio State University. He received a M.Sc. in Electrical Engineering and a Ph.D. in Electrical Engineering and Geo-Information Sciences from the Technical University of Budapest, Hungary. His research interests and expertise cover broad areas of spatial information sciences and systems, including photogrammetry and computer vision, navigation and georeferencing, multi-sensor geospatial data acquisition systems, such as GNSS/IMU and other sensor integration for navigation in GNSS-challenged environments, sensors and algorithms for indoor/personal navigation, image-based navigation using artificial intelligence (AI) methods, UAS and mobile mapping technologies. He has published over 400 journal and conference papers, several book chapters, and led/contributed to over 60 research projects sponsored by DOD, NASA, NGS, NGA, NSF, Federal DOT, Ohio DOT, etc.

Scalable Collaborative Swarm Mapping in GNSS-Denied Environments

Using drones for mapping/remote sensing has become a routine practice recently. However, flying multiple drones to jointly acquire geospatial/geoint data over an area is practically nonexistent. The objective of this effort is to develop a methodology, called **decentralized and scalable SLAM system** that will provide the missing technology that will allow for collaboratively navigate in and sense the area of interest, and work in GPS-challenged/denied environment. The key element of this research is to achieve a major milestone in drone utilizations by offering a collaborative navigation and mapping solution that is scalable and works in real-time. Scalability means that drones may join and leave the swarm any time without increasing the computation or communication demand or compromising the mapping performance. This is important, as drones may experience failures or be taken down by enemy or can recover from a malfunction or are released from the base.

The decentralized and scalable mapping and navigation swarm system consists of several cooperating sensing platforms and may operate in GPS-challenged/denied environment. While we refer to the sensing platforms as drones, the framework to be developed can be applied to other types of platforms, such as unmanned ground and underwater vehicles and robots, or even a group of soldiers. We expect that drones are equipped with low-cost camera, LiDAR, and GPS/GNSS and IMU sensors as well as may include magnetometer and UWB sensors. While the concept development is hardware independent, we do consider the current drone characteristics, such as the limited flight duration, low-cost on-board hardware, which, ultimately, present limitations in sensor and computation capabilities. Our system leverages the overlapping sensory data and combines the computation power of the individual drones via communication by using the proposed decentralized SLAM approach, which is fairly fault tolerant against individual drone and communication link failures.

The communication topology (information sharing between drones) is an important element of decentralized systems, directly affecting the overall system performance. There are three viable communication schemas for information sharing mechanisms: centralized, fully connected distributed, and scalable sharing. In the centralized solution, all nodes (drones) communicate with a central unit, and an optimal solution can be obtained, but this approach fails if the central unit malfunctions. The fully connected model eliminates the need for a central unit but overloads the communication channel. In the scalable communication model, nodes communicate within a certain range, allowing for a scalable solution. The ultimate goal of our research effort is to develop a data sharing and computation model that allows the implementation of decentralized and scalable swarm mapping systems that are able to asymptotically approach the performance of a centralized solution.

Helen Tran

Dr. Tran is an Intelligence Community postdoctoral fellow at Stanford University under the mentorship of Professor Zhenan Bao in the Chemical Engineering Department. She received her BS in Chemistry with a minor in Chemical Engineering from the University of California—Berkeley in 2009, conducting undergraduate research with Prof. Tsu-Jae King Liu (Electrical Engineering, Berkeley) and Prof. Christopher Schuh (Material Science, Massachusetts Institute of Technology). In the two subsequent years, Dr. Tran was a post-baccalaureate fellow and Scientific Engineering Assistant in Dr. Ronald Zuckermann's research group at the Molecular Foundry at Berkeley National Labs. She completed her PhD at Columbia University in 2016 under the supervision of Prof. Luis Campos. At Columbia University, she was awarded the National Science Foundation Graduate Research fellowship, the National Defense Science and Engineering Graduate fellowship, International Center for Materials Research fellowship, and George Pegram Award. Dr. Tran has been committed to scientific outreach (e.g. co-founded program between Columbia and Harlem charter school), endorses communication among interdisciplinary disciplines (e.g. co-founded seminar series at Columbia), and has mentored over twelve students (high school to graduate level). She was recently selected as a AAAS IF/THEN Ambassador for her outreach endeavors, leading to media opportunities such as being featured on the CBS TV show Mission Unstoppable and on the Girl Scouts Cadette Badge Workbook for Exploring STEM Careers. In January 2021, she will begin her independent careers as an Assistant Professor at the University of Toronto in the Department of Chemistry (co-appointed in the Department of Chemical Engineering

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Stretchable and Fully Degradable Semiconductors for Transient Electronics

Electronics that can be stretched like human skin and feature skin-inspired functionalities are opening doors for remarkable opportunities in health and environmental monitoring, next-generation consumer products, and sustainability. Notably, degradability is an attractive attribute for applications on dynamic surfaces where manual recovery would be prohibitively difficult and expensive. For example, fully biodegradable electronics promise to accelerate the integration of electronics with health by obviating the need for costly device recovery surgeries that also significantly increase infection risk. Moreover, the environmentally critical problem of discarded electronic waste would be relieved. A key component of such electronics is the development of a stretchable and degradable transistor with electrical performance independent of large mechanical stress. While numerous biodegradable insulators have been demonstrated as suitable device substrates and dielectrics for stretchable electronics, imparting biodegradability to electronically conducting and semiconducting materials for stretchable electronics presents a particular challenge due to the inherent resistance of most conductive chemistries to hydrolytic cleavage. Herein, we decouple the design of stretchability and transience by harmonizing polymer physics principles and molecular design in order to demonstrate for the first time a material that simultaneously possesses three disparate attributes: semiconductivity, intrinsic stretchability, and full degradability. We show that we can design acid-labile semiconducting polymers to appropriately phase segregate within a biodegradable elastomer, yielding semiconducting nanofibers which concurrently enable controlled transience and strain-independent transistor mobilities. This fully degradable semiconductor represents a promising advance towards developing multifunctional materials for skin-inspired electronic devices that can address previously inaccessible challenges and in turn create new technologies.

Jan van Aardt

Dr. Jan van Aardt obtained MS and PhD Forestry degrees, focused on remote sensing (imaging spectroscopy and lidar research), at Virginia Polytechnic Institute and State University, Blacksburg, Virginia in 2000 and 2004, respectively. This was followed by post-doctoral work at the Katholieke Universiteit Leuven, Belgium, and a stint as research group leader at the Council for Scientific and Industrial Research, South Africa. Imaging spectroscopy and structural (lidar) sensing of forests and crops form the core of his efforts, which vary between vegetation structural and system state (physiology) assessment. In context of the research presented at ICARS, he collaborates with the National Ecological Observatory Network's (NEON) Airborne Observation Platform (AOP) team to investigate lidar radiometry in forest canopies. He is currently a professor in the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology, New York.

Toward Enhanced 3D Sub-Canopy Mapping via Airborne/Spaceborne Full-Waveform LiDAR

Dr. Jan van Aardt (Rochester Institute of Technology; RIT)
Dr. Keith Krause (National Ecological Observatory Network; NEON)
Maj. Dr. Ben Roth (USAF; RIT)

This project is still in its award stage, and the research presented here thus are of precursory nature. This abstract and associated presentation highlights PhD-level work performed by Maj. Ben Roth (USAF), as part of a NRO-funded officer graduate program at RIT.

Lidar (light detection and ranging) remote sensing is a proven remote sensing modality for high accuracy/precision quantification of forest biophysical parameters, which are required for operational planning and management. Here we focus on the well-known significant effect of Bidirectional Scattering Distribution Functions (BSDF) on remote sensing of vegetation, especially since current radiative transfer simulations seldom take leaf BSDF into account. Furthermore, leaf directional scattering measurements also are scarce in literature, especially insofar as transmission is concerned. Most previous efforts are limited in their electromagnetic spectrum extent, lack validated models that extend past measured angles, and do not incorporate transmission scattering in an exhaustive fashion. In fact, most remote sensing simulations assume leaves with Lambertian reflectance, opaque leaves, or apply purely Lambertian transmission, even though the validity of these assumptions and the effect on simulation results are currently unknown. Dr. Roth captured deciduous broadleaf BSDFs (Norway Maple (*Acer platanoides*), American Sweetgum (*Liquidambar styraciflua*), and Northern Red Oak (*Quercus rubra*)), from the ultraviolet through shortwave infrared spectral regions (350-2500 nm), and accurately modeled the BSDF for extension to any illumination angle, viewing zenith, or azimuthal angle, as part of his PhD research. Relative leaf physical parameters were extracted from the microfacet models delineating the three species. He then explored leaf directional scattering effects on waveform lidar (wlidar) signals and their dependence on wavelength, lidar footprint, view angle, and leaf angle distribution (LAD), using RIT's Digital Imaging and Remote Sensing Image Generation (DIRSIG) simulation model. The most significant effects, when compared to Lambertian assumptions, were observed at visible wavelengths, small wlidar footprints, and oblique interrogation angles, relative to the mean leaf angles, respectively attributed to (i) a large specular component of the BSDF in the visible region, (ii) small footprints having fewer leaf angles to integrate over, and (iii) oblique angles causing diminished backscatter, due to forward scattering. *This knowledge will contribute to our NGA-funded effort to further investigate wlidar signal transmission through forest canopies, using both real and simulated wlidar data, and to attach probabilities to empty/filled 3D voxel spaces.*

Regina Werum

Dr. Regina E. Werum is a Professor of Sociology at the University of Nebraska-Lincoln (UNL). Her research revolves around the way social movements and policies shape and reflect social inequalities. Mostly quantitative, her projects frequently involve comparative-international and comparative-historical data. Her work has been funded by the Department of Defense, as well as the NSF, NEH, NAE, the Spencer and MacArthur Foundations, and Fulbright. Her research has appeared in top Sociology and specialty journals. Prior to joining UNL, she served as Associate Vice Chancellor for Research at the Office of Research and Economic Development at UNL and as a Program Director (Sociology) for the National Science Foundation.

Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model-and Data-Driven Approaches

Social unrest against government or state (in)actions fueled by socio-demographic or environmental factors is a great concern because of its potential impact on security and stability of any society at local, national, regional, and global scales. Of particular interest is the understanding and anticipating the cycles of contention for unrest that is challenging due to the ever-increasing volume, speed and variety of data (and noise) that is being generated, and the varying granularity of data (temporal, spatial and individual). Our *long-term goal* is to address these challenges by developing an *integrated model-driven and data-driven framework to anticipate social unrest events in a broad range of countries*. Model-driven approaches leverage human expertise, and social science-based theories to illuminate key factors—correlates and causes—underlying social unrest. Data-driven approaches exploit immediacy and comprehensiveness of data to discover patterns associated with unrest, help expand the models powered by algorithms, and inspire the model-driven social science efforts. Our goal is to examine the relationship of diverse thematic data that are increasingly becoming available in digital form including *Socio-demographic, Cultural, Environmental, Infrastructure, Geographic, Economic (SCEIGE) data*.

Currently we are 1) building our databases for SCEIGE data, unrest event data, and 5W analysis; 2) identifying and exploring SCEIGE factors that may behave as fuel or trigger for unrest events; 3) prototyping and evaluating an agent-based simulation framework for social unrest anticipation based on SCEIGE data; 4) developing a ground truth dataset for 5W analysis for the unrest events reported in news articles; and 5) establishing and validating novel algorithms that uses natural language processing and machine learning to accurately identify the location of unrest events.

So far we have 1) collected, curated, and analyzed data on various SCEIGE factors and proxies, including both news articles and existing datasets such as DesInventar, ACLED, ICEWS, GDELT, Census Data, CHIRPS data.; 2) performed exploratory and confirmatory factor analysis for various factors to discover their relationship with occurrence of protest; 3) developed a prototype multiagent simulation adopting a disease spread model to model how social unrest spreads spatially and over time; 4) extended our work on 5W analysis, in particular, to focus on improving our accuracy of extracting locations for social unrest events from newspaper articles; and 5) identified and will continue to evaluate the use of the Standardized Precipitation Index (SPI) as a proxy for agricultural productivity in the regions of interest. The current focus is on India. We will be expanding our scope to include Pakistan, Bangladesh, and Iraq in the next year.

Rebecca Willett

Dr. Rebecca Willett is a Professor of Statistics and Computer Science at the University of Chicago. Her research is focused on machine learning, signal processing, and large-scale data science. She completed her PhD in Electrical and Computer Engineering at Rice University in 2005 and was an Assistant then tenured Associate Professor of Electrical and Computer Engineering at Duke University from 2005 to 2013. She was an Associate Professor of Electrical and Computer Engineering, Harvey D. Spangler Faculty Scholar, and Fellow of the Wisconsin Institutes for Discovery at the University of Wisconsin-Madison from 2013 to 2018. Willett received the National Science Foundation CAREER Award in 2007, was a member of the DARPA Computer Science Study Group, and received an Air Force Office of Scientific Research Young Investigator Program award in 2010. Willett has also held visiting researcher or faculty positions at the University of Nice in 2015, the Institute for Pure and Applied Mathematics at UCLA in 2004, the University of Wisconsin-Madison 2003-2005, the French National Institute for Research in Computer Science and Control (INRIA) in 2003, and the Applied Science Research and Development Laboratory at GE Healthcare in 2002.

Analysis of High-Dimensional Autoregression Point Processes

This project focuses on estimating networks that describe influences within self-exciting (autoregressive) point processes, which model how current events trigger or inhibit future events, such as activity by one member of a social network can affect the future activity of his or her neighbors. A key challenge associated with these time series models is estimating this network when the number of variables is large -- meaning we are in the high-dimensional setting. Our team has made the following recent advances:

Detecting abrupt changes: High-dimensional self-exciting point processes have been widely used in many application areas to model discrete event data in which past and current events affect the likelihood of future events. In this paper, we are concerned with detecting abrupt changes of the coefficient matrices in discrete-time high-dimensional self-exciting Poisson processes, which have yet to be studied in the existing literature due to both theoretical and computational challenges rooted in the non-stationary and high-dimensional nature of the underlying process. We propose a penalized dynamic programming approach which is supported by a theoretical rate analysis and numerical evidence.

Context-dependent networks: While past work has focused on estimating the underlying network structure based solely on the times at which events occur on each node of the network, this project examines the more nuanced problem of estimating context-dependent networks that reflect how features associated with an event (such as the content of a social media post) modulate the strength of influences among nodes. Specifically, we leverage ideas from compositional time series and regularization methods to conduct network estimation for high-dimensional marked point processes. We provide theoretical guarantees for two estimators, which we validate by simulations and a synthetic data-generating model. We further validate our methods through two real data examples and demonstrate the advantages and disadvantages of both approaches.

Non-parametric sparse additive network models: Prior work has focused on parametric vector auto-regressive models. However, parametric approaches are somewhat restrictive in practice since many non-linear relationships are not easily captured by parametric models. A natural framework for dealing with this challenge in the regression setting is sparse additive models (SpAM). In this work, we provide both network estimation and prediction error guarantees for SpAM applied to network estimation. We provide sharp upper bounds on mean-squared error in terms of the sparsity, logarithm of the dimension, number of time points, and the smoothness of the RKHSs. We also provide numerical experiments that support our theoretical results and display potential advantages of using our non-parametric SpAM framework for a Chicago crime dataset.

Sunita Yadav

Sunita Yadav is currently a Crop Assessment Specialist with the U.S. Department of Agriculture - Foreign Agricultural Service (USDA-FAS) - International Production Assessment Division. In this role, she is responsible for commodity production estimates for Brazil using various data sources including remote sensing, commodity reports, and multi-scale country statistics.

Prior to joining the USDA, Sunita was an ORISE Visiting Scientist located at the NGA and USDA-FAS researching land abandonment, data collection protocols for machine learning, and crop classification using optical imagery. Her research interests include: remote sensing of agricultural and natural systems with optical and radar imagery, phenology, sampling design, ecological modeling, disease modeling, and reproducible science. With roots in integrated biology, she tries to apply her knowledge of evolutionary biology in her current work in remote sensing.

She received her B.S. in Computer Science from the University of Miami, M.A. in Geography from the University of Kansas, and a Ph.D. in Biological Science from the University of Cincinnati. Her dissertation research combined population genetic analysis with species distribution modeling to investigate environmental influences on breeding system distribution in a Hawaiian endemic plant genus. She has also worked on projects to understand species boundaries, plant-pollinator interactions in the Canadian Rockies, mapping persistence of bark beetle disturbance using an inter-annual time-series, and quantifying the performance of winter cover crops in the Chesapeake Bay.

Monitoring Agricultural Croplands Using Optical Time Series Imagery Data

In her role as an ORISE Visiting Scientist, Sunita Yadav, conducted research at the USDA International Production Assessment Division (IPAD) and at the NGA research directorate the past year. While at USDA IPAD, she continued her work on evaluating minimum data sampling requirements for accurate crop type classification for small grains in northern Africa. This approach provides IPAD with tools to customize sampling requirements for specific regions during crop tours.

At NGA, she worked on developing methods to better understand changes in Land Use, Tenure, and Management (LUTM). The drivers for LUTM are often correlated to socio-economic and/or political factors, with conflict being one of the more critical ones. While there is substantial research on land use change globally, only a handful of studies examine the complexity of such changes within conflict zones. This research focused on analyzing changes in agricultural productivity using multi-spectral optical data, potentially related to land abandonment, for a key region in West Africa. Public domain satellite imagery data were examined over the past 10 years to detect changes in vegetation signatures over time, and to tease out the patterns related to conflict factors versus environmental factors. Such research is important to increase understanding of the relationship between LUTM change and conflict, and to develop methods for monitoring these changes.

In her current role at USDA-IPAD, Sunita is interested to continue her research in data sampling, field delineation, and to analyze the effects of environmental factors on crop health and growth, crop phenotype, and pathogen distribution.