



Academic
Research
Symposium

7TH ANNUAL

INTELLIGENCE COMMUNITY ACADEMIC RESEARCH SYMPOSIUM

Program

WELCOME

Welcome to the seventh annual IC 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 researchers 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.

Dr. John Beiel is the Director, Science and Technology within ODNI, a role he was selected for in June 2019. In this position, Dr. Beiel 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.

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:

Air Force Institute of Technology
 FBI visiting scientist program
 IC Postdoctoral Research Fellowship Program
 National Intelligence University
 NGA Academic Research Program
 The Program on Extremism at George Washington University
 The Cybersecurity Manufacturing Innovation Institute
 UK IC Postdoctoral Research Fellowship Programme
 UTSA's National Security Collaboration Center





Keynote Speaker:

Brian T. Holmes, Ph.D.

Dean, National Intelligence University School of Science and Technology Intelligence

Dr. Holmes is the Dean of the School of Science and Technology Intelligence at the National Intelligence University in Bethesda, MD. The School is the focus for science and technical analytic education, research and external engagement across the intelligence and national security communities. He joined the University in 2012 to complement the existing members of the School and enable its burgeoning mission. The National Intelligence University was chartered by the Department of Defense in 1962, and the University's degrees — the Master of Science of Strategic Intelligence, the Master of Science and Technology Intelligence, and the Bachelor of Science in Intelligence — are authorized by Congress. The University is managed by the Defense Intelligence Agency (DIA), and receives strategic guidance from the Director of National Intelligence (DNI).

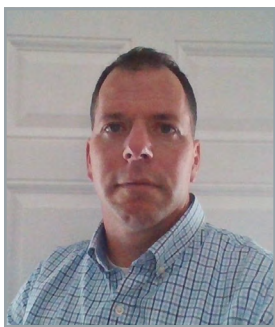
He received his B.S. in chemistry with a minor in history from the University of Delaware in 1997, and a Ph.D. in chemistry from Clemson University in 2002. After serving two years as a Post-Doctoral Associate in the University of Minnesota's Department of Chemical Engineering and Materials Science researching organic semiconductors, he accepted a two-year American Society for Engineering Education Fellowship with the U.S. Naval Research Laboratory in Washington, DC studying single electron nanotransistors.

Dr. Holmes served as an all-source intelligence analyst and Branch Chief in the Defense Intelligence Agencies' (DIA) Counterproliferation Support Office from 2006-2010 before accepting a managerial position in the Directorate for Analysis' Staff Operations Division.

He was a Direct Commission intelligence officer in the U.S. Navy Reserve, serving from 2007-2015 and reached the rank of Lieutenant (O-3). For three years, he supported the Afghanistan-Pakistan Task Force as an all-source intelligence analyst in DIA's Directorate for Intelligence (J2).

From 2012-2016, Dr. Holmes chaired the Emerging and Disruptive Technology, Geostrategic Resources and Environment, and Weapons of Mass Destruction concentrations in the School. He serves as an executive representative to the Scientific and Technical Intelligence Committee under the auspices of the National Intelligence Council, and directly supports Intelligence Community Directive 204 (National Intelligence Priorities Framework). He primarily focuses his research on dual use technologies, and the translation of emerging research and development into advanced materials for military systems. From 2016-2017, Dr. Holmes served as the Associate Dean of the School of Science and Technology Intelligence.

He holds two patents with the U.S. Navy, has published numerous peer reviewed scientific papers, and received the Deputy Director of National Intelligence for Analysis Distinguished Analysis Award, a National Intelligence Meritorious Unit Citation, and the 2018 Faculty Research Award. On August 07, 2017, Dr. Holmes qualified for the academic title of Professor of Intelligence. He served as a committee member on the study titled "A Strategy for Acquiring Secure and Reliable Electronic Components for Air Force Weapon Systems" for the Air Force Studies Board, a component of the National Academies of Sciences, and is a public sector liaison member of the Armed Forces Communications and Electronics Association's (AFCEA) Intelligence Committee.



Keynote Speaker:

LTC Thomas Pike, Ph.D.

National Intelligence University, IC Educator of the Year Awardee

LTC Thomas (Tom) Pike is faculty at the National Intelligence University and Technical Director of the Center for Anticipatory Intelligence and Adaptive Influence. He earned his PhD in Computational Social Science from George Mason University. His primary research interest is the collective intelligence of complex systems at the organizational and societal level. He has done research on multi-leveled networks and civil conflict.



Keynote Speaker:

Catherine Marsh, Ph.D.

Director, Intelligence Advanced Research Projects Activity (IARPA)

Dr. Catherine Marsh became director of the Intelligence Advanced Research Projects Activity in November 2019 where she is responsible for investing in high-risk/high-payoff research that has the potential to provide our nation with an overwhelming intelligence advantage. Prior to this assignment, Dr. Marsh was the chief scientist for the CIA's Directorate of Science and Technology from 2016-2019, where she was responsible for ensuring that leading-edge science and technology underlies current and future mission capabilities. Before that, she served as the dean of the DS&T's George Methlie School. Her first assignment at IARPA was from 2013-2015 as the deputy director. Dr. Marsh joined the CIA in 2001 and served in several capacities to innovate power solutions for the intelligence community. While in industry, she led the team that put lithium-ion technology on numerous platforms, including NASA's MARS exploration rovers Spirit and Opportunity. Dr. Marsh is a director of the National Intelligence Fellow and member of the DS&T's distinguished expert cadre. She holds a bachelor's and doctorate in inorganic and analytic chemistry from Brown University.

CONTENTS

Welcome	2
Keynote Speaker: Dr. Brian T. Holmes	3
Keynote Speaker: LTC Thomas Pike	4
Keynote Speaker: Dr. Catherine Marsh	4
Agenda	11
Loren Alegria	17
Microscopic Examination of Dissipative Processes in Quantum Materials	17
Alnur Ali	18
Slice-Driven Continuous Monitoring of Statistical Models: Localization, Detection, and Retraining	18
Wayne Austad	19
Next Generation Cybersecure Architectures Enable U.S. Manufacturing Innovation, Resilience, and Productivity	19
Laurie Gaskins Baise	20
Benchmark Data Development to Classify Damage for Natural Disaster Relief Efforts	20
David Barton	21
Towards Efficient Microwave-Optical Transduction in Integrated Lithium Niobate Fabry-Perot Photonic Crystal Cavities	21
John M. Beck	22
Spatial Dynamics and Analysis of Crops using Super Multispectral Image Resolution and Radar Fusion	22
Andrea Bertozzi	23
Active Learning Methods on Graphs for Image, Video and Multispectral Datasets	23
Srinivas Bettadpur	24
IGORSE: Integrating Geodetic Observations for Reconciled Scale Estimates	24
Eduardo Blanco	25
Mining Spatiotemporal Knowledge from Text and Images	25
Petko Bogdanov	26
Optimal Resolution for Dynamic Graph Mining	26
Harry Bostock	27
Developing a Trapped Ion Quantum RF and Microwave Sensor	27
Nick Byrd	28
Depolarizing Disagreement with Argument Maps, Discussion, and More	28
Debashis Chanda	29
Adaptive Infrared Thermal Signature Management	29
Jorge Chen	30
Building an Urban Digital Twin: A Research Agenda	30

Gordon Christie	31
Semantic Representations for Multi-Viewpoint Multimodal Geolocation	31
Ryan M. Corey	32
Cheating at the Cocktail Party Problem: Signal Processing Strategies for Semi-Blind Acoustic	
Source Separation and Enhancement	32
Curt H. Davis	33
DeePRK - Measuring Human Performance of DNN-Assisted Object Search and Detection over North Korea	33
Kyle Diederichsen	34
Understanding Multiscale Transport Challenges in Electrochemically Mediated Carbon Capture	34
Bryce Doerr	35
Safe and Uncertainty-Aware Robotic Motion Planning Techniques for Agile On-Orbit Assembly	35
Neel Doshi	36
Robotic Manipulation of Unknown Objects with Environmental Contacts	36
Ross Drummond	37
Modelling Tool for Li-ion Battery Pack Design	37
Lisa Durbeck	38
Scalable Partitioning of Sparse Stochastic Block Model Graphs via Graph Summarization	38
Saied El Faitori	39
Joint BEL and Clutter Loss Wideband Measurements in Modern Buildings	39
Timothy Erickson	40
Development of a Machine Learning Model to Predict Causes of Encephalitis	40
Ken Fowler	41
Next Generation Cybersecure Architectures Enable U.S. Manufacturing Innovation, Resilience, and Productivity	41
James Gooch	42
Multiplex Aptamer Biosensors for the Standoff Detection of Nerve Agents	42
Dodd Gray	43
Inverse Design of Waveguide Dispersion for Broadband Nonlinear Optics	43
Howard Grimes	44
Next Generation Cybersecure Architectures Enable U.S. Manufacturing Innovation, Resilience, and Productivity	44
Jason Gross	45
Localization and Planning for a UAV/Robot Team in Subterranean Environments	45
Carolyn Gunthardt	46
Two-Photon Excitation with Classical and Entangled Light	46
Junyi Guo	47
Improved Modelling of Gravity Variations Associated with Mass Transfers in the Earth System	
and Body Tide for More Precise Corrections of Gravity Measurements	47
Felipe Guzman	48
Optomechanical Gravimeters and Gravity Gradiometers	48

Preston Hartzell	49
Robust Confidence Measures for Multi-Temporal 3D Spatial Change Detection	49
Michael Hayes	50
Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model- and Data-Driven Approaches	50
Stephan Hlohowskyj	51
Attribution of Explosives and Explosive Precursors	51
Zhiting Hu	52
Toward Knowledge and Structure-rich Text Generation	52
Rachel Jones	53
A Groundwater Potentiality Investigation of Gulu District, Uganda using Fused Polarimetric Synthetic Aperture Radar and Magnetometry for Lineament Extraction	53
Juliette Jordan	54
Early Detection of Chemical-Induced Temporal Stress Signatures in GMO and Non-GMO Maize	54
Deepti Joshi	55
Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model- and Data-Driven Approaches	55
Despoina Kampouridou	56
Active Non-Foster Ultra-Broadband and Reconfigurable RF/Microwave Metamaterials	56
John Kerekes	57
Fundamental Research on Detection and Classification Limits in Spectral Imagery	57
Michael E. Ketterer	58
Uranium Isoscapes in Natural Waters: What Factors are Associated with Uranium Concentrations above 30 Micrograms/Liter?	58
Laura Kim	59
Absorption-Based Diamond Quantum Microscopy on Resonant Metasurfaces	59
Justin Knight	60
Extended Scene Wavefront Sensing Simulation Analysis	60
Andrew Lamb	61
Gravity Portals: Quantum Sensors for Enhanced Border Screening	61
Luce le Gorrec	62
Scalable Partitioning of Large Complex Networks	62
Jon Lewis	63
Analyzing Digital Footprints of January 6th Capitol Hill Rioters	63
Lia Ying Li	64
Optomechanical Sensing: Why So Sensitive?	64
Nebila Lichiheb	65
Improving the Prediction of Hazardous Material Dispersion in an Urban Environment	65

Lori Magruder	66
An Automated Terrain Model Correction Strategy using Icesat-2 for Global Geospatial Applications	66
Manoranjan Majji	67
Geomagnetic Pattern Recognition and Sensor Fusion for Alternative Positioning Applications	67
Panos P. Markopoulos	68
Tensor-Based Parametrization of Object Detection CNNs and Application to Aerial Imagery	68
Claire Marvinney	69
Quantum Sensing at Millikelvin Temperatures	69
David Messinger	70
Radiometrically Accurate Spatial Resolution Enhancement of Spectral Imagery for Improved Exploitation	70
Andrew Mines	71
Analyzing Digital Footprints of January 6th Capitol Hill Rioters	71
Sara Mouradian	72
Quantum Sensing of Intermittent Signals	72
Moussa N’Gom	73
Free Space Optical Communication Through Dynamic Media	73
Keng Tiong (Kelvin) Ng	74
Identification of Illegal Manufacturing Activity via Wastewater Markers	74
Laurel Orr	75
Bootleg: Chasing the Tail of Named Entity Disambiguation	75
Steven Owens	76
Pulsed Digital Holography System Efficiency Characterization	76
Chris Oxendine	77
Sensitivity Analysis of Varying Spatial Resolution on the Determination of Helicopter Landing Zones	77
Robert Pettit	78
Single Photon Emission from Donor Bound Excitons in ZnSe	78
Pencho Petrushev	79
Discrete Poisson Extension Algorithm for Downward Continuation of the Gravity Anomaly	79
Dieter Pfoser	80
Generation and Management of Crowdsourced Place Gazetteers – Human Mobility	80
Michelle L. Povinelli	81
Microstructured Materials with Engineered Thermal Emissivity	81
Andrew Sabelhaus	82
Soft Robot Locomotion: Not as Hard as You Might Think	82
Hady R. Salloum	83
Perspectives of Aural Mapping Using Small Unmanned Aircraft Systems (UAS)	83

Ashok Samal	84
Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model- and Data-Driven Approaches	84
Aswin Sankaranarayanan	85
Programmable Spectral Filter Arrays for Hyperspectral Imaging	85
Guillermo Sapiro	86
Blind and Federated Subgroup Robustness	86
Mubarak Shah	87
Video Geo-Localization Employing Geo-Temporal Feature Learning	87
Cyrus Shahabi	88
Deep Trajectory Clustering for Mobility-Behavior Analysis	88
Joseph Shaheen	89
MRQAP as a Causal-Comparative Tool in Relational Agent-Based Models	89
Shashi Shekhar	90
Identifying Aberration Patterns in Multi-attribute Trajectory Data with Gaps	90
Kevin Singh	91
Engineering and Control of Large-Scale Rydberg Atom Based Quantum Simulators	91
Todd Small	92
Solar Cell BRDF Measurement and Modeling with Out-of-Plane Data	92
Ryan Smith	93
Global Monitoring of Groundwater Storage Change Using Automated Assessment of Land Subsidence	93
Martin Smyth	94
Modeling Social Media Networks as Hyperbolic Random Graphs	94
Leen-Kiat Soh	95
Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model- and Data-Driven Approaches	95
Julie Spencer	96
Forecasting Dengue in Brazil at High Resolution	96
Steven Spiegel	97
Using Gaming Environments for Training Deep Learning Algorithms on Point Clouds	97
Cedric Spire	98
Automated Error Detection and Correction in Structured Databases	98
Bowen Tan	99
Toward Knowledge and Structure-rich Text Generation	99
Yun Tao	100
Metapopulation Dynamics of Outbreaks and their Management	100
Marko Tesic	101
The Impact of Explanations as Communicative Acts on Belief in a Claim: The Role of Source Reliability	101

Ammon Thompson	102
Learning about the Geospatial Spread of Pathogens from their Genomes	102
Susanna Todaro	103
Trapped-Ion Quantum Information with Metastable Qubits	103
Charles K. Toth	104
Scalable Collaborative Swarm Mapping in GNSS-denied Environment	104
Jan van Aardt	105
Toward Enhanced 3D Sub-Canopy Mapping Via Airborne/ Spaceborne Full-Waveform LiDAR	105
Lucy S. Vlietstra	106
Arctic GEOINT in Undergraduate Marine Science Research: Are Commercial Fishing Vessels	
Following Fish Poleward?	106
Regina E. Werum	107
Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model-	
and Data-Driven Approaches	107
Michael Weylandt	108
Statistical Analysis of Multiple Network Structures and Signals	108
Robert Wible	109
Toward Enhanced 3D Sub-Canopy Mapping Via Airborne/ Spaceborne Full-Waveform LiDAR	109
Clark Wilson	110
Environmental Sources of Gravity Variations at a Mountain Site	110
William “Will” C. Wright	111
Sensitivity Analysis of Varying Spatial Resolution on the Determination of Helicopter Landing Zones	111
Eric P. Xing	112
Toward Knowledge and Structure-rich Text Generation	112
Dillon C. Yost	113
Computational Investigation of 2D Materials for Electromagnetic Interference Shielding	113
Stella Yu	114
Actionable Representation Learning from Natural Data	114
Simon Zwieback	115
Satellite-Based Mapping of the Susceptibility to Permafrost Terrain Instability	115
Mark Zumberge	116
Acquisition, Deployment, and Testing of an Absolute Quantum Gravity Meter for Hydrological	
Measurements and Adaptation to Seafloor Geodesy	116

AGENDA

DAY ONE, WEDNESDAY, 15 SEPTEMBER 2021

Session One: Remote Sensing

- 12:00-12:20 ICARS Opening Introduction: **Dr. Brian T. Holmes**
- 12:20-12:50 **Dr. Hady Salloum:** Perspectives of Aural Mapping Using Small Unmanned Aircraft Systems (UAS)
- 12:50-1:00 Break**
- 1:00-1:30 **Dr. Lori Magruder:** Gravity Portals: Quantum Sensors for Enhanced Border Screening
- 1:30-1:40 Break**
- 1:40-2:10 **Dr. Jorge Chen:** Building an Urban Digital Twin: A Research Agenda
- 2:10-2:20 Break**
- 2:20-2:50 **Dr. Ryan Smith:** Global Monitoring of Groundwater Storage Change Using Automated Assessment of Land Subsidence
- 2:50-3:00 Break**
- 3:00-3:30 **Dr. Rachel Jones:** A Groundwater Potentiality Investigation using Fused Polarimetric SAR and Magnetometry for Lineament

Session Two: Big Data/ Network Analytics

- 12:20-12:50 **Wayne Austad, Ken Fowler, and Dr. Howard Grimes:** Next Generation Cybersecure Architectures Enable U.S. Manufacturing Innovation, Resilience, and Productivity
- 12:50-1:00 Break**
- 1:00-1:30 **Dr. Lisa Durbeck:** Scalable Partitioning of Sparse Stochastic Block Model Graphs via Graph Summarization
- 1:30-1:40 Break**
- 1:40-2:10 **Dr. Michael Weylandt:** Statistical Analysis of Multiple Network Structures and Signals
- 2:10-2:20 Break**
- 2:20-2:50 **Dr. Joseph Shaheen:** MRQAP as a Causal-Comparative Tool in Relational Agent-based Models
- 2:50-3:00 Break**
- 3:00-3:30 **Dr. Martin Smyth:** Modeling Social Media Networks as Hyperbolic Random Graphs

Session Three: Electro Optics

- 12:20-12:50 **Dr. Dodd Gray:** Inverse Design of Waveguide Dispersion for Broadband Nonlinear Optics
- 12:50-1:00 Break**
- 1:00-1:30 **Capt. Steven Owens:** Pulsed Digital Holography System Efficiency Characterization
- 1:30-1:40 Break**
- 1:40-2:10 **Dr. Simon Zwieback:** Satellite-Based Mapping of the Susceptibility to Permafrost Terrain Instability
- 2:10-2:20 Break**
- 2:20-2:50 **Dr. Dillon Yost:** Computational Investigation of 2D Materials for Electromagnetic Interference Shielding
- 2:50-3:00 Break**
- 3:00-3:30 **Maj. Todd Small:** Solar Cell BRDF Measurement and Modeling with Out-of-Plane Data

Session Four: Artificial Intelligence/ Machine Learning

- 12:20-12:50 **Dr. Mubarak Shah:** Video Geo-Localization Employing Geo-Temporal Feature Learning
- 12:50-1:00 **Break**
- 1:00-1:30 **Dr. Stella Yu:** Actionable Representation Learning from Natural Data
- 1:30-1:40 **Break**
- 1:40-2:10 **Steve Spiegel:** Using Gaming Environments for Training Deep Learning Algorithms on Point Clouds
- 2:10-2:20 **Break**
- 2:20-2:50 **Dr. Panos Markopoulos:** Tensor-Based Parametrization of Object Detection CNNs and Application to Aerial Imagery
- 2:50-3:00 **Break**
- 3:00-3:30 **Dr. Eric Xing, Dr. Zhiting Hu, and Dr. Bowen Tan:** Toward Knowledge and Structure-Rich Text Generation

Session Five: Chemical Sensing Science

- 12:20-12:50 **Dr. Keng (Kelvin) Tiong Ng:** Identification of Illegal Manufacturing Activity via Wastewater Markers
- 12:50-1:00 **Break**
- 1:00-1:30 **Dr. Kyle Diederichsen:** Understanding Multiscale Transport Challenges in Electrochemically Mediated Carbon Capture
- 1:30-1:40 **Break**
- 1:40-2:10 **Dr. Ross Drummond:** Modeling tool for Li-ion Battery Pack Design
- 2:10-2:20 **Break**
- 2:20-2:50 **Dr. Juliette Jordan:** Early Detection of Chemical-Induced Temporal Stress Signatures in GMO and Non-GMO Maize
- 2:50-3:00 **Break**
- 3:00-3:30 **Dr. Carolyn Gunthardt:** Two-Photon Excitation with Classical and Entangled Light

Session Six: Quantum

- 12:20-12:50 **Dr. Kevin Singh:** Engineering and Control of large-Scale Rydberg Atom Based Quantum Simulators
- 12:50-1:00 **Break**
- 1:00-1:30 **Dr. Loren Alegria:** Microscopic Examination of Dissipative Processes in Quantum Materials
- 1:30-1:40 **Break**
- 1:40-2:10 **Dr. Susanna Todaro:** Trapped-ion Quantum Information with Metastable Qubit
- 2:10-2:20 **Break**
- 2:20-2:50 **Dr. Ying Lia Li (Lia):** Optomechanical Sensing: Why so Sensitive?
- 2:50-3:00 **Break**
- 3:00-3:30 **Dr. Sara Mouradian:** Quantum Sensing of Intermittent Signals

DAY TWO, WEDNESDAY, 22 SEPTEMBER 2021

Session One: Big Data/Network Analytics

- 12:00-12:20 Keynote: **LTC Thomas Pike**: Intelligence Developed from Adaptive Systems
- 12:20-12:50 **Dr. Cyrus Shahabi**: DETECT: Deep Trajectory Clustering for Mobility-Behavior Analysis
- 12:50-1:00 Break**
- 1:00-1:30 **Dr. Dieter Pfoser**: Generation and Management of Crowdsourced Place Gazetteers – Human Mobility
- 1:30-1:40 Break**
- 1:40-2:10 **Dr. Gordon Christie**: Semantic Representations for Multi-Viewpoint Multimodal Geolocation
- 2:10-2:20 Break**
- 2:20-2:50 **Dr. Eduardo Blanco**: Mining Spatiotemporal Knowledge from Text and Images
- 2:50-3:00 Break**
- 3:00-3:30 **Dr. Laurel Orr**: Bootleg: Chasing the Tail of Named Entity Disambiguation

Session Two: Chemical Sensing and Gravimetry

- 12:20-12:50 **Dr. Michael Ketterer**: Uranium Isoscapes in Natural Waters: What Factors are Associated with Uranium Concentrations Above 30 Micrograms/Liter?
- 12:50-1:00 Break**
- 1:00-1:30 **Dr. Lucy Vliestra**: Arctic GEOINT in Undergraduate Marine Science Research: Are Commercial Fishing Vessels Following Fish Poleward?
- 1:30-1:40 Break**
- 1:40-2:10 **Dr. Stephan Hlohowskyj**: Attribution of Explosives and Explosive Precursors
- 2:10-2:20 Break**
- 2:20-2:50 **Dr. Junyi Guo**: Improved Modeling of Gravity Variations Associated with Mass Transfers in the Earth System and Body Tide for more Precise Corrections of Gravity Measurements
- 2:50-3:00 Break**
- 3:00-3:30 **Dr. Mark Zumberge**: Acquisition, Deployment, and Testing of an Absolute Quantum Gravity Meter for Hydrological Measurements and Adaptation to Seafloor Geodesy

Session Three: Remote Sensing

- 12:20-12:50 **Dr. Preston Hartzell**: Robust Confidence Measures for Multi-Temporal 3D Spatial Change Detection
- 12:50-1:00 Break**
- 1:00-1:30 **Col. Christopher Oxendine** and **LTC William Wright**: Sensitivity Analysis of Varying Spatial Resolution on the Determination of Helicopter Landing Zones
- 1:30-1:40 Break**
- 1:40-2:10 **Dr. Ryan Corey**: Cheating at the Cocktail Party Problem: Signal Processing Strategies for Semi-Blind Acoustic Source Separation and Enhancement
- 2:10-2:20 Break**
- 2:20-2:50 **Dr. Jan van Aardt** and **Lt Col. Robert Wible**: Toward Enhanced 3D Sub-Canopy Mapping Via Airborne/ Spaceborne Full-Waveform LiDAR
- 2:50-3:00 Break**
- 3:00-3:30 **Dr. John Beck**: Spatial Dynamics and Analysis of Crops using Super Multispectral Image Resolution and Radar Fusion

Session Four: Electro Optics

- 12:20-12:50 **Dr. Saied El Faitori:** Joint BEL and Clutter Loss Wideband Measurements in Modern Buildings
- 12:50-1:00 **Break**
- 1:00-1:30 **Dr. Justin Knight:** Extended Scene Wavefront Sensing Simulation Analysis
- 1:30-1:40 **Break**
- 1:40-2:10 **Dr. Despoina Kampouridou:** Active Non-Foster Ultra-Broadband and Reconfigurable RF/Microwave Metamaterials
- 2:10-2:20 **Break**
- 2:20-2:50 **Dr. Moussa N'Gom:** Free Space Optical Communication Through Dynamic Media
- 2:50-3:00 **Break**
- 3:00-3:30 **Dr. Felipe Guzman:** Optomechanical Gravimeters and Gravity Gradiometers

Session Five: Quantum

- 12:20-12:50 **Dr. Robert Pettit:** Single Photon Emission From Donor Bound Excitons in ZnSe
- 12:50-1:00 **Break**
- 1:00-1:30 **Dr. Claire Elizabeth Marvinney:** Quantum Sensing at Millikelvin Temperatures
- 1:30-1:40 **Break**
- 1:40-2:10 **Dr. Laura Kim:** Absorption-Based Diamond Quantum Microscopy on Resonant Metasurfaces
- 2:10-2:20 **Break**
- 2:20-2:50 **Dr. David Barton:** Towards Efficient Microwave-Optical Transduction in Integrated Lithium Niobate Fabry-Perot Photonic Crystal Cavities
- 2:50-3:00 **Break**
- 3:00-3:30 **Dr. Harry Bostock:** Developing a Trapped Ion Quantum RF and Microwave Sensor

Session Six: Robotics

- 12:20-12:50 **Dr. Andrew Sabelhaus:** Soft Robot Locomotion: Not as Hard as You Might Think
- 12:50-1:00 **Break**
- 1:00-1:30 **Dr. Bryce Doerr:** Safe and Uncertainty-Aware Robotic Motion Planning Techniques for Agile On-Orbit Assembly
- 1:30-1:40 **Break**
- 1:40-2:10 **Dr. Neel Doshi:** Robotic Manipulation of Unknown Objects with Environmental Contacts
- 2:10-2:20 **Break**
- 2:20-2:50 **Dr. Jason Gross:** Localization and Planning for a UAV/Robot Team in Subterranean Environments
- 2:50-3:00 **Break**
- 3:00-3:30 **Dr. Charles Toth:** Scalable Collaborative Swarm Mapping in GNSS-denied Environment

DAY THREE, WEDNESDAY, 29 SEPTEMBER 2021

Session One: Big Data/Network Analytics

- 12:00-12:20 **Keynote: Dr. Catherine Marsh:** Intelligence Advanced Research Projects Activity (IARPA)
- 12:20-12:50 **Dr. Luce Le Gorrec:** Scalable Partitioning of Large Complex Networks
- 12:50-1:00 Break**
- 1:00-1:30 **Dr. Shashi Shekhar:** Identifying Aberration Patterns in Multi-Attribute Trajectory Data with Gaps
- 1:30-1:40 Break**
- 1:40-2:10 **Dr. Cedric Spire:** Automated Error Detection and Correction in Structured Databases
- 2:10-2:20 Break**
- 2:20-2:50 **Dr. Petko Bogdanov:** Optimal Resolution for Dynamic Graph Mining
- 2:50-3:00 Break**
- 3:00-3:30 **Dr. Timothy Erickson:** Development of a Machine Learning Model to Predict Causes of Encephalitis

Session Two: Social Dynamics

- 12:20-12:50 **Dr. Deepti Joshi, Dr. Ashok Samal, and Dr. Leen-Kiat Soh:** Leveraging Environment and Culture to Anticipate Social Unrest with Integrated Model-and Data-Driven Approaches
- 12:50-1:00 Break**
- 1:00-1:30 **Dr. Regina Werum and Michael Hayes:** Climate Extremes and Protest in India: A Cross-Disciplinary Analysis
- 1:30-1:40 Break**
- 1:40-2:10 **Dr. Nicholas Byrd:** Depolarizing Disagreement With Argument Maps, Discussion, And More
- 2:10-2:20 Break**
- 2:20-2:50 **Dr. Marko Tesic:** The Impact of Explanations as Communicative acts on Belief in a Claim: The Role of Source Reliability
- 2:50-3:00 Break**
- 3:00-3:30 **Jonathan Lewis and Andrew Mines:** Analyzing Digital Footprints of January 6th Capitol Hill Rioters

Session Three: Spectral Science

- 12:20-12:50 **Dr. Michelle Povinelli:** Microstructured Materials with Engineered Thermal Emissivity
- 12:50-1:00 Break**
- 1:00-1:30 **Dr. David Messinger:** Radiometrically Accurate Spatial Resolution Enhancement of Spectral Imagery for Improved Exploitation
- 1:30-1:40 Break**
- 1:40-2:10 **Dr. Aswin Sankaranarayanan:** Programmable Spectral Filter Arrays for Hyperspectral Imaging
- 2:10-2:20 Break**
- 2:20-2:50 **Dr. Debashis Chanda:** Adaptive Infrared Thermal Signature Management
- 2:50-3:00 Break**
- 3:00-3:30 **Dr. John Kerekes:** Fundamental Research on Detection and Classification Limits in Spectral Imagery

Session Four: Gravetometry

- 12:20-12:50 **Dr. Srinivas V Bettadpur:** IGORSE: Integrating Geodetic Observations for Reconciled Scale Estimates
- 12:50-1:00 **Break**
- 1:00-1:30 **Dr. Clark Wilson:** Environmental Sources of Gravity Variations at a Mountain Site
- 1:30-1:40 **Break**
- 1:40-2:10 **Dr. Andrew Lamb:** Gravity Portals: Quantum Sensors for Enhanced Border Screening
- 2:10-2:20 **Break**
- 2:20-2:50 **Dr. Manoranjan Majji:** Geomagnetic Pattern Recognition and Sensor Fusion for Alternative Positioning Applications
- 2:50-3:00 **Break**
- 3:00-3:30 **Dr. Pencho Petrushev:** Discrete Poisson Extension Algorithm for Downward Continuation of the Gravity Anomaly

Session Five: Artificial Intelligence/Machine Learning

- 12:20-12:50 **Dr. Curt Davis:** DeePRK: Measuring Human Performance of DNN-Assisted Object Search and Detection over North Korea
- 12:50-1:00 **Break**
- 1:00-1:30 **Dr. Guillermo Sapiro:** Blind and Federated Subgroup Robustness
- 1:30-1:40 **Break**
- 1:40-2:10 **Dr. Alnur Ali:** Slice-Driven Continuous Monitoring of Statistical Models: Localization, Detection, and Retraining
- 2:10-2:20 **Break**
- 2:20-2:50 **Dr. Andrea Bertozzi:** Active Learning Methods on Graphs for Image, Video and Multispectral Datasets
- 2:50-3:00 **Break**
- 3:00-3:30 **Dr. Laurie Baise:** Benchmark Data Development to Classify Damage for Natural Disaster Relief Efforts

Session Six: Chemical Sensing

- 12:20-12:50 **Dr. Nebila Lichiheb:** Improving the Prediction of Hazardous Material Dispersion in an Urban Environment
- 12:50-1:00 **Break**
- 1:00-1:30 **Dr. Yun Tao:** Metapopulation Dynamics of Outbreaks and their Management
- 1:30-1:40 **Break**
- 1:40-2:10 **Dr. Julie Spencer:** Forecasting Dengue in Brazil at High Resolution
- 2:10-2:20 **Break**
- 2:20-2:50 **Dr. James Gooch:** Multiplex Aptamer Biosensors for the Standoff Detection of Nerve Agents
- 2:50-3:00 **Break**
- 3:00-3:30 **Dr. Ammon Thompson:** Learning About the Geospatial Spread of Pathogens from their Genomes



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 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, developing applications of the quantum anomalous hall effect.

As an Intelligence Community Postdoctoral Fellow, he works with Amir Yacoby at Harvard.

Microscopic Examination of Dissipative Processes in Quantum Materials

Microfabrication entails a complex chemical environment that can make it difficult to infer the underlying reasons for the performance of a given qubit. As occurred for classical information processors, coherence in quantum circuits will advance in lockstep with advances in device metrology. I will describe two recent experiments aimed at clarifying the microscopic dynamics that limit coherence in superconducting qubits. In the first we demonstrate how it is possible to generate Bogoliubov quasiparticles within a nanometer-scale volume, a technique that simulates how dissipative disturbances propagate within a quantum circuit. Second, I will describe a technique in which a superconducting cavity is coupled to a surface, enabling a precise measurement of local dissipation in as-fabricated devices.



Alnur Ali

Dr. Alnur Ali is an Intelligence Community Postdoctoral Fellow at Stanford University, working with John Duchi on various problems in statistics and optimization. He received his Ph.D. in machine learning, working with Ryan Tibshirani, at Carnegie Mellon University. Before that, he spent several years at Microsoft and Microsoft Research as a data scientist, improving the quality of Microsoft Bing's search engine. Nowadays, he is broadly interested in statistics, machine learning, and convex optimization, with a focus on getting statistical models and machine learning systems to actually run smoothly in the "wild".

Slice-Driven Continuous Monitoring of Statistical Models: Localization, Detection, and Retraining

A lot of attention has been (and continues to be) paid to improving the accuracy of predictive models, over the last couple decades. This has been for good reason: statistical models that have been intensely studied by statisticians and computer scientists alike can now be readily found on the critical path in many real-world machine learning systems. Somewhat less well-studied -- but just as important, and challenging -- are the many issues that arise once a statistical model has been deployed to a live site, and must now be maintained.

In this paper, we take a step in this direction, and study the fundamental problem of identifying subpopulations in a stream of data on which the performance of a deployed statistical model has degraded. We propose a simple method, by drawing on ideas from the literatures on detection and conformal inference, for identifying these "hard slices" of the data. We show, theoretically and empirically, that our method is able to find qualitatively meaningful subpopulations, and also improve the accuracy of a model after retraining it on these hard subpopulations. Our proposal has applications beyond the pure management of deployed statistical models, and can be used for online (or batch) anomaly detection more broadly.



Wayne Austad

Chief Research & Development Officer, The Cybersecurity
Manufacturing Innovation Institute

Wayne Austad has worked at Idaho National Laboratory for 28 years with more than 20 years of experience leading impactful national security programs. As CTO for National & Homeland Security he leads the strategy for R&D programs, collaborative partnerships, and the Secure & Resilient Cyber Physical Systems Initiative. Previously as Technical Director of the Cybercore Integration Center, he led the creation of a new research and education campus dedicated to control systems cybersecurity and national partnerships that address targeted cyber threats to U.S. critical infrastructure.

Next Generation Cybersecure Architectures Enable U.S. Manufacturing Innovation, Resilience, and Productivity

Cyber attacks are at an all-time high. Manufacturers are at significant risk as they are the targets through multiple threat vectors. As the manufacturing supply chain races to digitize their systems, they often unknowingly open themselves up to new vulnerabilities in their IT and OT systems. Bad actors have found multiple ways to infiltrate company data to create havoc, potentially costing companies millions of dollars. Attackers can hold operations hostage, impact quality, and damage product life cycles. To protect their people, processes, and technologies, companies must go beyond surface-based cybersecurity and harden their systems to be secure-by-design.

CyManII is the future state of cybersecurity. We connect cybersecurity and energy efficiency to create manufacturing solutions that keep America's companies competitive and protected.

CyManII's intelligent transformation is critical if the United States is to be the global leader in manufacturing. Combining physical, cyber, and energy layers in legacy and new systems of manufacturing, this intelligent transformation requires starting with an Energy Efficient (ε) Pervasive, Unobtrusive, Resilient, and Economical (ε-PURE) secure manufacturing architecture. Linking these secure manufacturing architectures to increases in overall equipment energy efficiency, CyManII provides manufacturers more productivity and more profit. CyManII's secure manufacturing architectures reduce the time to making quality parts – reducing initial scrap parts and generating more profit. Hence, CyManII makes a company more robust (protecting systems and machines from cyber-attacks) and resilient (faster recovery after a cyber breach).

Through our six institutional foundational tasks (IFTs), CyManII is on the path toward establishing expectations for quality security that will be followed and highly respected by OEMs, SMMs, OTs and integrators to help them achieve secure energy savings by overcoming common barriers and re-establish the United States' as a proactive global innovator for manufacturing, cybersecurity and energy efficiency; attaining cyber innovation to secure U.S. manufacturing.



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 has been funded by the U.S. Geologic Survey, the National Science Foundation, DTRA, and the National Geospatial Intelligence Agency.

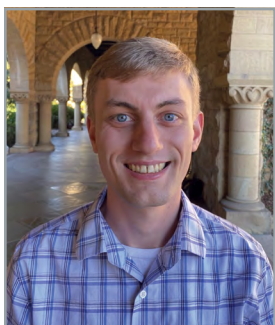
Benchmark Data Development to Classify Damage for Natural Disaster Relief Efforts

Laurie G. Baise, Babak Moaveni, Magaly Koch, Christina Sanon, and Adel Asadi

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 are building and optimizing a benchmark image library of damage features for testing and training automated supervised classification algorithms. In the first year of the project, we developed ground failure labels (e.g. liquefaction and landslides) using imagery from the 2010 Haiti earthquake, 2011 Christchurch earthquake, 2016 Kumamoto earthquake, and the 2020 Puerto Rico earthquake. The imagery labels were drawn from reconnaissance field reports and attached to polygons drawn from the imagery. Attributes include ground failure type, color, infrastructure damage, label confidence. The current benchmark image library includes approximately 2000 labeled polygons for ground failure.

We are also evaluating the existing building damage datasets xView and xbd as training libraries for automated classification in new events. The xView dataset with 30 cm spatial and 8-bit radiometric resolutions and including 1067 labeled demolished buildings was used to identify collapsed buildings in WorldView Google Earth optical imagery from the 2017 M7.1 Puebla, Mexico earthquake with the 50 cm spatial and 8-bit radiometric resolutions. We have used a modified U-net style fully convolutional neural network (CNN), in which intrinsic local and global image features are learned through patches of different windows size. Posterior probability heat maps generated by the networks are used iteratively as context information along with the original image patches to learn the shape and connectedness of the demolished buildings to discriminate them from non-demolished buildings. The results show that the proposed framework has 78% accuracy in detecting the demolished buildings from intact buildings within the xView dataset. To this end, we tested the network on 97 buildings including 10 demolished by feeding imagery and building footprints into the trained algorithm. The true positive rate for intact and demolished buildings were 89% and 60%, respectively.

Another aspect of our work is to pair imagery with geospatial variables related to earthquake ground failure to improve performance of automated classifications. In this study, pre- and post-event sets of high-resolution aerial and satellite imagery, provided by MAXAR WorldView and Geospatial Information Authority of Japan (GSI) paired with geospatial predictions of liquefaction modeling, and geospatial event, topographic, and environmental variables, were used to map landslides initiated by a series of earthquakes in Kumamoto, Japan in April 2016. We use the USGS preferred geospatial model for landslide probability as an input, as well as, Peak Ground Acceleration, distance to epicenter, slope, elevation, land cover and precipitation. Detailed and complete landslide occurrence inventories of the area were provided by Kyoto University's Disaster Prevention Research Institute and National Research Institute for Earth Science and Disaster Resilience (NIED) after performing post-Earthquake investigations. The selection of effective parameters was done via a machine learning-based feature selection algorithm. Thus, the model turns from a pure computer vision tool into an integrated model in order to achieve a higher prediction accuracy by considering physical parameters' data in addition to the optical imagery.



David Barton

Dr. David Barton is a postdoctoral fellow in Marko Lončar's group at Harvard's School of Engineering and Applied Sciences. He received his bachelor's degree *summa cum laude* in Chemical Engineering from the University of Minnesota in 2015. He then received his master's degree (2018) and PhD (2020) in Materials Science and Engineering as a Stanford Graduate fellow at Stanford University, working with Prof. Jennifer Dionne. His PhD work developed a new platform for resonant, reconfigurable, and nonlinear phase gradient metasurfaces using guided mode resonances in nanoantennas. His work has been published in *Nature Nanotechnology*, *Physical Review Letters*, *Nano Letters*, and *Applied Physics Letters*. During his PhD, he was a finalist for SPIE's "Active Photonics" series best paper competition in 2017 and was a 2019 Materials Research Society Graduate Student Award winner. As an Intelligence Community Postdoctoral fellow, David is investigating new integrated cavity designs for microwave-optical transduction and integrated photonics in thin-film Lithium Niobate. Outside of the lab, David is passionate about ceramic arts, French patisserie, and traveling.

Towards Efficient Microwave-Optical Transduction in Integrated Lithium Niobate Fabry-Perot Photonic Crystal Cavities

David Barton, Jeffrey Holzgrafe, Di Zhu, Hana Warner, Neil Sinclair, and Marko Loncar

Microwave photons are a powerful and versatile tool for computation and sensing technologies spanning quantum and classical regimes. Superconducting qubits, for example, are an advanced platform for quantum computers operating at microwave frequencies. As technologies like this scale, computing units will need to be interfaced and connected over long distances to form quantum networks. Microwave thermal noise at room temperature and signal attenuation means that ultracold temperatures are required. Unfortunately, the cooling demands are too large for purely microwave technologies to be useful in this context. Interfacing these microwave quantum states with other, low-loss frequencies will allow high-fidelity transmission of quantum information.

Microwave-optical transduction is an attractive method to achieve this. Entanglement between a microwave and optical photon allows transduction of quantum information by way of quantum teleportation. Entangled photon pairs have also been suggested as a method for advanced remote quantum sensing applications. In integrated platforms, it has been difficult to simultaneously achieve high-efficiency transduction while maintaining low added noise, hampering the effectiveness of these technologies.

Here, I will present our work developing an integrated microwave-optical transducer using lithium niobate on insulator. Using a resonant pump, we aim to create entangled optical and microwave photons through the electro-optic effect. Thin-film lithium niobate on insulator is an excellent electro-optic material and has been shown to operate well at microwave frequencies. High efficiency transduction requires both low loss rates of the microwave and optical cavity modes (i.e., a high Q factor), as well as small overall cavity sizes (i.e., a small mode volume). To generate the three required resonances, our design relies on a structure with a microwave cavity and two coupled optical cavities that host two resonances whose frequencies differ by the microwave cavity frequency. Our optical cavity is an integrated Fabry-Perot cavity formed by a straight optical waveguide sandwiched between two photonic crystal mirrors. This geometry balances the need for small mode volumes while maintaining high quality factors for both the optical and microwave cavities. We explore a variety of mirror designs and show our progress in developing high quality factor resonances ($Q > 1$ million) and small mode volume (cavity length < 100 microns) cavities. We conclude by looking at future devices and experiments that will be used to demonstrate efficient quantum transduction.



John M. Beck

John M. Beck, Ph.D. works as a Principal Research Scientist III for the University of Alabama in Huntsville's (UAH) Information Technology and Systems Center (ITSC). Dr. Beck specializes in using machine learning, geospatial analysis, remote sensing, and data analytics to solve real world problems. John 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. He is a retired U.S. Army Reserves Engineer Officer and combat veteran.

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 (MSIC) 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. While at Auburn, he provided technical and managerial expertise in developing, coordinating, and leading Agricultural, Soil, and Water Quality related research and extension environmental education projects for the Alabama Cooperative Extension System (ACES). From 1995 to 1997, he worked as a Remote Sensing /Geographic Information Systems Specialist with Lockheed-Martin with 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

Researchers at the University of Alabama in Huntsville's Information Technology and Information Center (UAH/ITSC) are using deep learning to develop a method of pan-sharpening multispectral imagery (MSI) and fusing synthetic radar (SAR) data. Results will provide an enriched Geospatial Intelligence (GEOINT) product that could be used for a variety of applications to include the spatial analysis of agricultural crops. UAH developed and evaluated three different Convolutional Neural Networks (CNNs). The first CNN was a simple unsupervised CNN model comprised of a series of layer blocks and fusion units. Each fusion unit consisted of the following components: concatenation of the panchromatic data with the latent high resolution (HR) MSI patch; convolutional layers; an additive skip connection of the convolution output and the output of the model's first convolution layer. The output of the model was evaluated using a loss function that was the sum of three metrics. These metrics were intended to evaluate each one of three aspects of the output: spatial quality and consistency with respect to the panchromatic data; spectral consistency with respect to the original multispectral data; and quality with no reference (QNR) index. The second model's architecture consisted of a simple generative adversarial network (GAN) that consisted of a generator and discriminator branch. The generator branch attempted to produce a higher quality image than the MSI using the high resolution pixel details of the panchromatic imagery, each attempt was passed through the discriminator which determined if parameters needed to be adjusted to generate a suitable image. The discriminator and generator were made up of convolution layers, batch normalization, and leaky rectified linear unit (ReLU) activations. An adam optimizer was used to handle gradients. The third CNN was based on a totally different strategy in which the spectral values from the bands of the MSI were used to colorize corresponding features in the panchromatic image. This CNN was also based on a simple GAN design in which there were two constituent models: a generator and a discriminator. The training set was constructed by down sampling and up sampling the MSI. The degraded MSI was used as input to the generator network, and the original MSI was used as a ground truth for training the discriminator. The generator accepted the degraded MSI and a single-band grayscale image as input. The degraded MSI was then converted to grayscale during training, but the panchromatic image was used during testing. The generator extracted spatial features from the grayscale image while mapping the color from the MSI to the learned spatial features. UAH is currently evaluating the results from each CNN; however the third CNN using the colorization theory shows great promise.



Andrea Bertozzi

Dr. Andrea Bertozzi is an applied mathematician with expertise in geometric methods for data science and many other topics in applied mathematics ranging from fluid dynamics to social science modeling. Dr. 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 first as Associate Professor of Mathematics and then as Professor of Mathematics and Physics. Dr. Bertozzi moved to UCLA in 2003 as a Professor of Mathematics. In 2018 she became a Distinguished Professor of Mathematics and Mechanical and Aerospace Engineering since 2018. She has held the Betsy Wood Knapp Chair for Innovation and Creativity at UCLA since 2013. Since 2005 she has served as Director of Applied Mathematics, overseeing the graduate and undergraduate research training programs at UCLA. Dr. Bertozzi is a member of the US National Academy of Sciences and a Fellow of the American Academy of Arts and Sciences. She was awarded SIAM's Kleinman Prize in 2019 and is a fellow of the American Mathematical Society, the Society for Industrial and Applied Mathematics, and the American Physical Society. To date she has graduated 41 PhD students and has mentored over 41 postdoctoral scholars.

Active Learning Methods on Graphs for Image, Video and Multispectral Datasets

There is a need for automated classifiers for data that include human analysts as part of the algorithm, providing hand-labelled information about select key pieces of data. This kind of “active learning” is a growing area of research in machine learning. There are several categories of active learning approaches: disagreement-based methods, margin-based methods, clustering-based methods, and optimization-based methods. Our work fits into the last two categories. Active learning combines two different ideas – the first is a general method for semi-supervised learning. The second is a method to strategically choose a small amount of unlabeled data to send to the “human in the loop” for ground truth classification. This project develops rigorous theory along with code for generalized graph-based Bayesian models for active learning with both sequential active learning, batch learning, and multiple classes. Specific types of data considered are hyperspectral and multimodal imagery and video, and synthetic aperture radar.



Srinivas Bettadpur

Dr. Bettadpur is a space geodesist, and studies the Earth's variable gravity field, orientation and shape from a space-based vantage point. His interest in the mechanical Earth evolved when his early education in celestial mechanics, perturbation theories, and orbit determination merged with his growing fascination with the eternally moving Earth and its fluid components. His interest in this science and in engineering practices led to his current active involvement in architecture development for space missions and large-scale observation systems. He teaches orbital mechanics, space geodesy, and estimation.

Dr. Bettadpur is a Fellow of the International Association of Geodesy (IAG), and an Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA). He received the NASA Exception Public Achievement Medal in 2018, the European Geosciences Union Vening-Meinesz Medal in 2016.

Other Information:

Dr. Bettadpur joined the tenured faculty ranks in the ASE/EM Department at UT Austin in 2015. From 2010-2015, he held the title of Research Professor, prior to which he had been a Senior Research Scientist at the UT Center for Space Research.

Srinivas Bettadpur obtained his Ph.D. in Aerospace Engineering from The University of Texas at Austin in 1993. Prior to that, he obtained an MS from the University of Oklahoma in 1987, and an MTech from the Indian Institute of Technology Kanpur (India), both in Aerospace Engineering. He obtained his B.Eng. in Mechanical Engineering from the Punjab Engineering College in Chandigarh (India).

IGORSE: Integrating Geodetic Observations for Reconciled Scale Estimates

The scientific objectives of our research are to understand the sources and consequences of the scale factor mismatch between global terrestrial reference frame realizations from the independent geodetic techniques. We are developing the needed theory and algorithms to understand and characterize the unique elements of this problem for the sea-level science as well as positioning, navigation and timing applications. At the conclusion of this work, we anticipate being able to articulate a scale factor error reduction roadmap that is a mix of improvements to data processing strategies, potential improvements to hardware capabilities, and signal processing methodologies.

The proposed work entails activities that span improvements to basic theoretical understanding, alternate technical approaches, numerical investigations, and field investigations. Dedicated synthesis activity integrates the results obtained by co-investigators. We are working to improve the understanding of the errors in our knowledge of the Earth's gravitational parameter. We are innovating in the use of laser metrology for mm-accuracy inter-system ties at the km-scales, which helps reduce a km-scale network of physical infrastructure to a fiducial point. These lead to improved uncertainty quantification in estimates of scales from current geodetic modeling practices; and improved theoretical understanding of the role of scale and other reference frame parameters in science and navigation applications.

Our research is essential and directly applicable to the NGA mission, connected to assured access to reliable PNT capabilities, to Enrich GEOINT towards Earth Observation, Geophysics, and Geomatics. This work improves the exploitation of high precision GEOINT products and geospatial information. The contributions through geodesy extend to both the NGA national security objectives and to Federal disaster relief objectives. Reference frames are the foundational basis for representing geospatial information and reckoning change, and the proposed work advances NGA GEOINT mission in this arena.



Eduardo Blanco

Dr. Eduardo Blanco is an Associate Professor in the School of Computing, Informatics, and Decision Systems Engineering at Arizona State University. He conducts research primarily in natural language processing with a focus on computational semantics, including semantic relation extraction and intricate linguistic phenomena such as negation, modality, and uncertainty. He is interested in both fundamental research and applications in the social sciences, medicine, and robotics among others. 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 recipient of the Bloomberg Data Science Research Grant and the National Science Foundation CAREER Award.

Mining Spatiotemporal Knowledge from Text 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 experimental results and analyses to provide insights into this challenging problem.



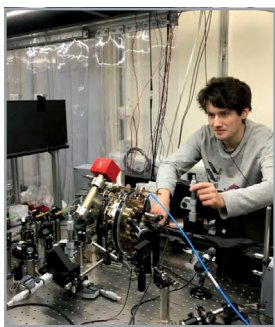
Petko Bogdanov

Dr. Petko Bogdanov is an Associate Professor in the computer science department at University at Albany - SUNY. His research interests include data mining and management with applications to network science, bioinformatics, nanomaterial design and sociology. Previously, he was a postdoctoral fellow in the department of computer science at University of California, Santa Barbara. He received his PhD and MS in Computer Science from the University of California, Santa Barbara in 2012 and his BE in Computer Engineering from the Technical University of Sofia in 2005. His research has been sponsored by NSF, NGA, DARPA, ONR and ARL. Dr. Bogdanov serves as an associate editor for the IEEE Transactions on Knowledge and Data Engineering since 2019 and is serving as a program committee member on multiple data mining and machine learning conferences. He is a member of the IEEE and the ACM.

Optimal Resolution for Dynamic Graph Mining

Dynamic graph mining can elucidate the activity of in-network processes in diverse application domains from social, mobile and communication networks to infrastructure and biological networks. Compared to static graphs, the temporal information of when graph events occur is an important new dimension for improving the quality, interpretation and utility of mined patterns. However, mining dynamic graphs poses an important, though often overlooked, challenge: observed data must be analyzed at an appropriate temporal and spatial resolution, commensurate with the underlying rate and span of application-specific processes. If, for example, the temporal resolution for analysis is too high, evidence for ongoing processes may be fragmented; if it is too low, data relevant to multiple ongoing processes may be mixed, thus obstructing discovery. Existing approaches for dynamic graph mining typically adopt a fixed timescale (e.g., minutes, days, years), disregard temporal structure (e.g., periodicity, burstiness, trends) and mine for patterns in the corresponding aggregated graph snapshots. However, scale-aware methods must consider non-uniform resolution across both time and the graph, and thus, account for heterogeneous network processes evolving at varying rates in different graph regions.

This talk will present recent work supported by the National Geospatial-Intelligence Agency on learning an appropriate resolution in time and the graph while optimizing downstream applications. The first half of the talk will be dedicated to temporal signals over graphs, i.e., time series associated with the nodes within a fixed structure. A novel graph-time dictionary decomposition that exploits interpretable structures in the data for improved summarization, missing values imputation, interpolation and community detection will be introduced. The second half of the talk will focus on estimating the optimal timescale for discrete diffusion and network growth processes and demonstrate that employing the correct resolution in time allows for better parameter estimation, cascade growth prediction and missing data recovery. The conclusion of the talk will discuss the future directions being considered as part of the project.



Harry Bostock

Dr. Harry Bostock is an UK Intelligence Community Postdoctoral fellow at the University of Sussex studying how to exploit trapped Ytterbium ions for quantum sensing for RF and microwave detection. Dr. Bostock's 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 and achieved a MPhys degree at Swansea University, where he completed a fascinating project on efficient methods of compressing electron plasma to assist with the trapping of anti – hydrogen using Penning

traps and rotating DC electrodes.

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 ($\sim$ Hz), while our sensor should be effective at high RF (1 MHz – 150 MHz) and even 12.6 GHz ($\pm$ 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 $\sim$ 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 ~ 1 ms. 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!



Nick Byrd

Dr. Nick Byrd is a philosopher-scientist researching how to better understand and improve individuals and groups' decision-making and well-being. Dr. Byrd is an Intelligence Community (IC) Postdoctoral Research Fellow at Stevens Institute of Technology.

Simon Cullen is a faculty member and serves as Dr. Byrd's Research Advisor for the IC Postdoctoral Research Program at Carnegie Mellon University using cognitive science to address problems in decision science and philosophy.

Depolarizing Disagreement with Argument Maps, Discussion, and More

Presenters: Nick Byrd (Stevens Institute of Technology) and Simon Cullen (Carnegie Mellon University)

Reasoning tends to be influenced not only by prior beliefs, but also by epistemic identity (Byrd, under review). For example, people who identify as politically conservative sometimes evaluate arguments and evidence differently than those who identify as politically liberal (e.g., Kahan et al., 2017). We wanted to understand whether and how easy-to-implement critical thinking interventions might overcome such partisan effects in reasoning. Arguments for controversial policies were presented in standard prose or as argument maps. Replicating and extending prior work (Cullen & Sharma, 2018), argument maps nearly eliminated the partisan evaluation of the prose arguments ($d > 0.6$)—an effect that is largely the result of higher argument ratings from the opponents of the policy. Also, higher cognitive reflection test performance correlated with lower argument evaluations, especially when arguments were intentionally presented as logically invalid. In ongoing work, we are testing the judgment-improving and depolarizing effects of discussion with a disagreeing peer and various incentive schemes. We are also exploring ways to understand the psychological and neural mechanisms involved in disagreement, depolarization, and reflective reasoning.



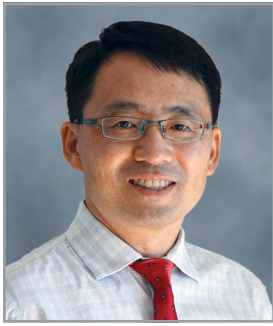
Debashis Chanda

Prof. Debashis Chanda is a Professor, jointly appointed with NanoScience Technology Center, Dept. of Physics and College of Optics and Photonics (CREOL), University of Central Florida (UCF). Dr. Chanda received his PhD from University of Toronto. His PhD work was recognized in the form of several awards, including prestigious National Sciences and Engineering Research Council (NSERC) fellowship. Dr. Chanda completed his post-doctoral research with Prof. John A. Rogers at Beckman Institute, University of Illinois at Urbana-Champaign. Quite a few of this research works were extensively covered by National

Science Foundation news, BBC, Daily Mail, NBC, Fox, Science Radio and other national/international media outlets. His research has appeared on American Scientist magazine as focused article where it was outlined how companies like Intel, Toshiba etc are trying to adopt some of the printing techniques which were developed in his group. Dr. Chanda is a recipient of the 2012 DOE Energy Frontier Research Center (EFRC) Solar Energy Future Direction Innovation Proposal Award, 2013 NSF Summer Institute Fellowship and International Displaying Future Award-2016 by Merck Germany, UCF Reach of the Stars Award (2018), UCF Luminary Award (2020) etc. Dr. Chanda's research has been supported by NSF, DARPA, Florida Space Institute/NASA, State of Florida, Northrop Grumman, Lockheed Martin etc. Apart from that Dr. Chanda is founder of couple of start-ups out of his research in California.

Adaptive Infrared Thermal Signature Management

There is a need for the development of IR camouflaging technology that will be beneficial for military applications. Our proposed solution involves the use of Engineered Optical Materials (EnMat) that promises dynamic tunability of IR properties. Two EnMat systems are considered, both of which consist of a nanostructured surface that is coupled to an optical cavity. The EnMat is designed such that it diffracts light in the visible domain, but can be imaged in the IR domain using infrared cameras. By incorporating a phase change material VO_2 , in the optical cavity, we show that the optical response of the EnMat can be controlled based on the semiconducting (transparent) or metallic (reflective) states of VO_2 . We provide proof of concept demonstration that the VO_2 based EnMat devices provide an extra layer of security such that the coded information can be concealed to infrared cameras unless we drive the VO_2 to its semiconducting state. The high-definition (HD) pixelated dynamically tunable IR devices will revolutionize the IR camouflage, thermal management, infrared tagging and labelling. Further, development of the concept in spray-able paint format allows low cost, high throughput scalability of the concept to any surfaces.

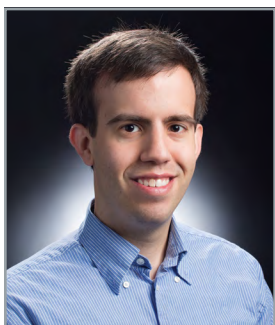


Jorge Chen

Dr. Jorge Chen is a research scientist at the Oak Ridge Institute for Science and Education (ORISE). His research centers on 3D urban mapping, indoor cartography, and mobile mapping, with an emphasis on multi-sensor fusion and accuracy assessments. His recent research has focused on automating the creation of 3D maps of urban environments; fusing 3D geometry from omni-directional images with laser scans; assessing the spatio-temporal accuracy of 3D remotely sensed data; and developing software for mobile scanning systems.

Building an Urban Digital Twin: A Research Agenda

Geographic information systems (GIS) and remote sensing systems have revolutionized the world of mapping over the past five decades, making worldwide geospatial information available at anytime from anywhere. While much of this information exists in two-dimensional (2D) and vertically extruded 2.5D formats, there is growing recognition that 3D information can significantly expand geospatial capabilities beyond what currently exists, especially in urban spaces. A sampling of these enhanced capabilities for urban areas include solar potential studies, urban farming, noise studies, vertical property management, urban mining, and disaster response—such as studying the impact of a high-rise building collapse, among many others. This presentation will examine the current state of 3D mapping in urban areas, with an emphasis on the open CityGML international standard, and outline a research agenda examining the automatic generation of CityGML features using remotely sensed data.



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

As more unmanned platforms come online, it becomes increasingly difficult for analysts to keep up with the deluge of data. Artificial intelligence and machine learning tools hold tremendous potential as a force multiplier; however, fundamental challenges remain related to cross-platform and cross-view analysis. Our research focuses on leveraging both ground and aerial datasets to develop models capable of generalizing to a diverse set of viewpoints. We show that it is possible to achieve performance improvements and robustness across views by training neural networks with a shared backbone on disparate datasets. We also show progress developing models capable of performing visual geolocation using satellite base maps. Together, these tools can help overcome challenges related to cross-platform and cross-view analysis.



Ryan M. 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 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" and the 179th ASA Meeting Best Student Paper Award for the presentation "Dynamic range compression of sound mixtures."

Cheating at the Cocktail Party Problem: Signal Processing Strategies for Semi-Blind Acoustic Source Separation and Enhancement

Both human and machine listeners struggle to hear in crowded, noisy environments with many competing sound sources. The problem of separating sounds from overlapping sources is called the cocktail party problem. Signal processing researchers have spent decades working on the hardest version of the problem, called blind source separation, where no prior information is available about the sources or sensors. State-of-the-art blind algorithms struggle to separate more than two or three sources and to adapt to changing conditions. But in real applications, we can often exploit additional information about the signal content, such as a known speech keyword used to activate a voice assistant, or about source and microphone placement, such as a wearable device on a moving talker. In some applications, such as immersive human listening systems, we can enhance a set of signals without fully separating them. This talk explores signal processing strategies using application-specific information or criteria to achieve better performance than fully blind source separation methods.



Curt H. 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.

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

Within the last five years, Deep Neural Networks (DNNs) 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 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.

We trained 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 Analysis branches. Traditional human visual searches (unassisted) were first performed over two quarter geocell AOIs, e.g. $0.25^\circ \times 0.25^\circ$ lat x long, for each feature/object class to establish a baseline set of human performance metrics. Then, DNN-assisted searches were 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 central database. A variety of metrics (*F1*, precision, recall, search rate, etc.) are computed to quantitatively assess human performance metrics for both the traditional and DNN-assisted object search and detection.

The overall results from the two-year project effort indicate that the machine-assisted human search metrics outperformed the traditional visual searches for 6 out of 14 feature/object classes based on the composite *F1* score. In addition, the machine-assisted searches were on average 30 times faster than the traditional visual searches and represent a significant savings in human labor hours.



Kyle Diederichsen

Dr. Kyle Diederichsen is an Intelligence Community Postdoctoral Fellow at the Massachusetts Institute of Technology with Professor T. Alan Hatton in the Department of Chemical Engineering. He earned his bachelor's degree in Chemical Engineering from the University of Colorado at Boulder, where he spent time working on the self-assembly of block copolymer thin films and earned the Marilyn and Howard L. Anseth Outstanding Undergraduate Research Award. For his doctoral work, Kyle attended the University of California, Berkeley, working with Professor Bryan McCloskey. His dissertation focused on the design and characterization of high transference number polymer – based electrolytes for lithium batteries. As a Postdoctoral Fellow he has focused on electrochemically mediated carbon capture, considering both electrolyte design and system engineering. Kyle has received multiple awards for outstanding teaching during his graduate career, and served at various levels of graduate student government. At MIT, Kyle has led the Postdoctoral Association's Diversity, Equity, and Inclusion Committee, advocating for improved hiring practices across the Institute, and support and recognition for groups supporting underrepresented populations.

Understanding Multiscale Transport Challenges in Electrochemically Mediated Carbon Capture

The continuing release of carbon dioxide into the atmosphere has significantly increased the rate of climate change. In recent years, record temperatures and more extreme weather patterns have been linked more directly to the global average temperature rise. As these effects continue to grow, they may even contribute to destabilizing governments and increasing terrorism. Given the continued delay in substantial carbon emissions reductions, carbon capture is increasingly seen as a critical component in reducing the long term impacts of climate change. Carbon capture, both from point sources to reduce emissions and from distributed capture directly from air, has been studied extensively for many years, but additional advances are needed to reduce the cost and energy requirements. Most carbon capture techniques make use of a large swing in temperature and/or pressure to capture CO_2 . In these systems, sorbents are exposed to CO_2 at low temperature or high pressure, causing them to uptake CO_2 . To regenerate the sorbent, the temperature is raised or a vacuum is applied so that the CO_2 is released. This purified CO_2 can then be sent for storage or conversion to other chemicals. While significant progress has been made in such systems, the high energy and cost associated with them has continued to be a barrier for wide implementation.

Recently, there has been a substantial interest in applying electrochemical regeneration techniques to carbon capture. In these systems, sorbent molecules react with CO_2 and then a voltage is applied which modulates the molecule's affinity for CO_2 and causes it to release. By acting directly on the capture agent, system energetics can be reduced because there is no need to heat or apply vacuum to portions of the system which are not active for capture. In addition, by being electrically driven, such systems can be tied very directly to renewable power and scaled to fit different carbon capture scenarios. This could enable visions of highly distributed carbon capture devices. However, the transport of CO_2 into the liquid electrolyte necessary for electrochemical techniques to react with the sorbent molecule is still a significant barrier to enable implementation. We have worked to address and understand this complex transport challenge both at the molecular scale in electrolyte design and formulation, and at the system level through engineering of gas contacting devices. Tying together these vastly different length scales will significantly advance the science of electrochemically mediated carbon capture, and begin to tackle the grand challenge of climate change.



Bryce Doerr

Dr. Bryce Doerr is an Intelligence Community Postdoctoral Fellow in the Department of Aeronautics and Astronautics at MIT. He received B.S., M.S., and Ph.D. degrees in Aerospace Engineering and Mechanics from the University of Minnesota – Twin Cities. His current work includes on-orbit robotic assembly of space structures and control of large collaborative swarms using Random Finite Sets. His research interests include motion planning, optimal control, estimation, and reinforcement learning for space systems including satellites, robotics, and swarms. He also holds a position as an Aerospace

Engineer working on guidance, navigation, and control at the NASA Goddard Space Flight Center.

Safe and Uncertainty-Aware Robotic Motion Planning Techniques for Agile On-Orbit Assembly

As access to space and robotic autonomy capabilities move forward, there is simultaneously a growing interest in deploying large, complex space structures to provide new on-orbit capabilities. New space-borne observatories, large orbital outposts, and even futuristic on-orbit manufacturing will be enabled by robotic assembly of space structures using techniques like on-orbit additive manufacturing which can provide flexibility in constructing and even repairing complex hardware. However, the dynamics underlying the robotic assembly system during manipulation may operate under uncertainties (e.g. changing inertial properties). Thus, inertial estimation of the robotic assembler and the manipulated additively manufactured component must be considered during the structural assembly process. The contribution of this work is to address both the motion planning and control for robotic assembly with consideration of the inertial estimation of the combined free-flying robotic assembler and additively manufactured component system. Specifically, the Linear Quadratic Regulator Rapidly-Exploring Randomized Trees (LQR-RRT*) and dynamically feasible path smoothing are used to obtain obstacle-free trajectories for the system. Further, model learning is incorporated explicitly into the planning stages via approximation of the continuous system and accompanying reward of performing safe, objective-oriented motion. Remaining uncertainty can then be dealt with explicitly via robust tube model predictive control techniques. By obtaining controlled trajectories that consider both obstacle avoidance and learning of the inertial properties of the free-flyer and manipulated component system, the free-flyer rapidly considers and plans the construction of space structures with enhanced system knowledge. The approach naturally generalizes to repairing, refueling, and re-provisioning space structure components while providing optimal collision-free trajectories under e.g., inertial uncertainty.



Neel Doshi

Dr. Neel Doshi is an Intelligence Community (IC) post-doctoral fellow advised by Professor Alberto Rodriguez at the Massachusetts Institute of Technology, where he focuses on developing methods for planning and controlling contact-rich robotic manipulation and designing novel robot end-effectors. He graduated with a B.S. in Mechanical Engineering (2012) and a M.S. in Robotics (2013) from the University of Pennsylvania. He earned his PhD (2019) from Harvard University under the supervision of Professors Robert Wood and Scott Kuindersma, where he worked on the design of millimeter-scale robots, including the Harvard Ambulatory MicroRobot (HAMR), and created algorithms for planning and controlling the locomotion of legged robots at this scale. Neel's research is broadly focused on developing synergistic mechanical and algorithmic solutions that allow robots to make purposeful and reliable contact with real-world objects and surfaces. He is the recipient of the Intelligence Community post-doctoral fellowship in 2019 and the NDSEG graduate research fellowship in 2013. He is also a co-author on publications that received the Best Automation Paper award at ICRA 2014 and the Best RAL Paper Award for 2021, as well as on publications that were nominated for the Best Paper Award at IROS 2017 and ICRA 2018.

Robotic Manipulation of Unknown Objects with Environmental Contacts

Robots that purposefully manipulate their environment will play an important role in future space missions; for example, by performing on-orbit robotic servicing and assembly, clearing space debris, or utilizing resources found in-situ. An underlying skill common to all these tasks is the ability handle potentially unknown objects in unstructured environments. This is a challenging *joint* estimation and control problem, where the robot must estimate important object and environmental properties while simultaneously controlling both the object's pose and the relevant contact interactions. In this talk, I will describe the development of the low-level estimation and control capabilities that can be used to solve this problem. Specifically, using only the robot's proprioception and force sensing at the wrist for feedback, we develop a series of closed-loop, object-agnostic, primitive motions that the robot uses to estimate key object and environmental properties. Based on this information, the object-agnostic primitives are then refined for improved and more precise control. As a verification of this approach, I will show several demonstrations of a robot manipulator purposefully manipulating unknown two-dimensional polygonal objects.

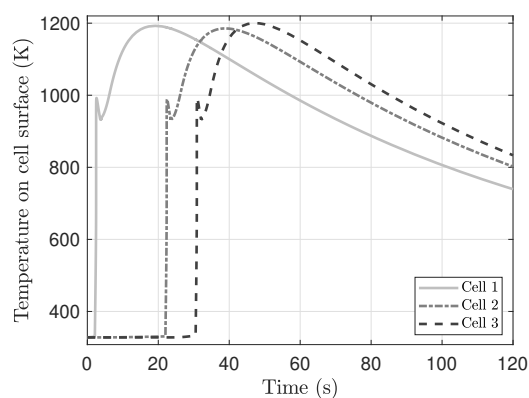


Ross Drummond

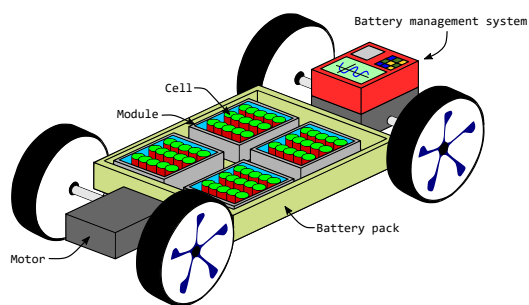
Dr. Ross Drummond received a D.Phil. in control engineering from the University of Oxford, U.K (2013-2017) where he is currently a UK Intelligence Community Postdoctoral Research Fellow in the Control Group. His main research interests include the stability analysis of nonlinear feedback systems which he combines with more applied research on the modelling and design of electrochemical energy storage devices, including Li-ion batteries and supercapacitors.

Modelling Tool for Li-ion Battery Pack Design

Li-ion batteries are an enabling technology behind the electrification of a wide range of technologies, including vehicles, portable electronics and aviation. As battery technology develops, greater demands are being placed on pack-level performance to obtain light, energy-dense yet safe electrically powered systems. However, the complexity underlying Li-ion battery dynamics makes predicting their response challenging, leading pack designers to adopt conservative packs designs, e.g. with excessive cell spacing to prevent thermal runaway. To reduce this conservatism, this talk introduces a suite of modelling tools for Li-ion battery packs to understand the trade-off between pack energy density and safety from thermal runaway. The model is parameterised for the Panasonic NCR18650GA cells of the RRC 2054-2 pack and includes features such as the distribution of currents across parallel connected packs, thermal effects and the potential for cascading thermal runaway. Future work will explore parametrising the model against other commercially available cells and incorporating additional electrochemical phenomena such as ageing effects and fast charging protocols.



(a) Thermal runaway cascading through three cells in a pack.



(b) Illustration of an electric vehicle battery pack.

Figure 1: Model to quantify trade-off between battery pack safety Vs. energy density.

Lisa Durbeck

Dr. Lisa Durbeck is an Intelligence Community 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 Partitioning of Sparse Stochastic Block Model Graphs via Graph Summarization

This research project aims to distill useful data out of publicly available data sources; to encode the data in a convenient way for various assessments; to summarize the relationships within the data succinctly; and to represent the activity and changes in particular entities and groups within the data across time succinctly. This talk will report on recent work in detecting communities within graphs.

Community detection is a focused strategy within clustering where the objective is to discover highly-connected subgraphs in a graph, and partition the graph along these natural fault lines into distinct communities. Community detection is an NP-hard problem for which computationally efficient approximations have long been sought. Methods have sought a balance between accuracy, simplicity, latency, and memory usage. In this talk, we assess the suitability of recent progress in a minimum description-length (MDL) based approach to graph summarization to the problem of community detection.

We assess a recently described graph summarization method, DPGS, that lossily encodes the graph using fewer nodes and edges while maintaining key properties of the original, such as skewed node degrees and graph spectrum, and maintains an error bounds on the perturbation of the graph's eigenvalues. While these features were chosen by its designers to improve the graph reconstruction model, we show within a 40-graph dataset from the DARPA / MIT public graph challenge that DPGS preserves the latent communities within the graph. In addition, we find that the summarization reduces the graph encoding ~30%.

We compare the elapsed running time and output quality to the performance of a partitioning technique that makes use of a mature eigensolver, Locally Optimal Block Conjugate Gradient method (LOBPCG) by Knyazev. It performs spectral clustering, deriving a community partition by first finding the eigen-decomposition of the graph normalized Laplacian matrix, then assigning node labels based on the eigenvectors, using the clusterQR method by Damle. This approach has time order approximately $O(N \cdot k)$, where k is the number of communities. DPGS time complexity in our experiments when used for clustering is between $O(E)$ and $O(N \cdot E)$ where N is the number of nodes and E the number of edges in the graph, depending on how long we allow the algorithm to search for more compression. More work is needed to tune the algorithm to the community detection problem in order to tighten these estimates.

Index Terms—Computation (stat.CO); Graph partition; graph sparsification; graph summarization; MDL; locality sensitive hashing; spectral graph theory; LOBPCG; spectral graph partitioning; stochastic block models; community detection



Saied El Faitori

Dr. Saied El Faitori is a UK Intelligence Community Postdoctoral Research Fellow awarded in October 2020: The fellowship is offered by the Government Office for Science and administered by the Royal Academy of Engineering for at least two years.

Dr. El Faitori was awarded a PhD. degree of EEE in August 2020 from Durham University under the title (Multi-band Wideband Channel Measurements in Indoor and Outdoor Environments above 6 GHz for 5G Networks). The PhD thesis investigated the frequency dependence in the millimetre wave (mmWave) band of different parameters such as path

loss, delay spread and angular spread. In addition, Dr. El Faitori was awarded a MSc. degree of EEE from University of Garyounis (Benghazi) in 2006, and a BSc. degree of EEE awarded from University of Garyounis (Benghazi) 1993.

Joint BEL and Clutter Loss Wideband Measurements in Modern Buildings

Fifth generation (5G) radio systems use millimetre waves frequency bands to achieve high data rates. These bands however have different transmission properties than the usual lower frequencies, such as higher transmission loss from outside to inside a building called building entry loss and from the presence of obstacles such as buildings and vegetation between the transmitter and receiver called clutter loss. Previous measurements and international recommendations have measured these two effects separately. It is the purpose of this study to estimate the combined effects by conducting measurements in typical cluttered scenarios and in different types of buildings using the custom designed high performance radio measurement capability at Durham University which covers multiple frequency bands recently allocated by the world radiocommunications conference (WRC19) for 5G radio systems. For comparative and modelling purposes the measurements will be performed across a wide frequency range and the results will be used to generate a new model which can be applied for such scenarios. The model will enable the selection of the appropriate frequency to avoid interference and to reduce the electromagnetic threat. The model will be also submitted to the international telecommunications union to update their recommendations.

In addition, measurements of typical building materials were conducted in the controlled environment of the anechoic chamber at Durham University to understand their effect on the transmission of such signals. The penetration loss measurements were conducted with different incident angles from -30 degrees to +30 degrees with 5-degree steps where at zero angle the antenna was perpendicular onto the building material, for five frequency bands (28, 39, 50, 60 and 70 GHz). To measure the penetration loss for each frequency band, the measurements were performed with and without material, where the penetration loss equals the difference between the two measurements. The results show an increase in penetration loss as the frequency increases, the lowest value was at zero angle and it was more than 30 dB for most of the tested materials at angles larger than 10 degrees on either sides from the zero angle, where narrow-beam lens antennas were used (4.5 and 2.2 degrees).

Future work

Reflection coefficient measurements for building materials in the anechoic chamber for the same frequency bands. The results of these measurements and the penetration loss measurements will be submitted to the ITU Study Group 3. Building entry loss and clutter loss measurements to be conducted at Durham University buildings; in addition to the arranged measurements with the Ministry of Defence following end of lockdown.



Timothy Erickson

Dr. Timothy Erickson is an Intelligence Community Postdoctoral Fellow working with the Center for Human Immunobiology at Texas Children's Hospital and the Murray lab of the Baylor College of Medicine's National School of Tropical Medicine. He received his PhD in epidemiology from the University of Texas Health Science Center at Houston in 2019. His research interests lie in the development of improved diagnostic capabilities for infectious diseases, specifically those caused by *Rickettsia* and parasites. His fellowship project uses machine learning approaches, both supervised and unsupervised, in a

complimentary manner to provide insights into the etiology of pediatric encephalitis and to provide a clinical tool to support diagnosis and triage.

Development of a Machine Learning Model to Predict Causes of Encephalitis

Background: Encephalitis is an inflammation of the brain resulting in substantial morbidity and mortality. More than 100 causes of encephalitis, the majority of which are infectious agents, have been identified. More recently, autoimmune etiologies of encephalitis have been identified. Despite recent advancements in diagnostic technologies, 40-70% of encephalitis cases never have a cause identified.

Methods: We employed a machine learning approach to create a predictive model to assist in the diagnosis of encephalitis cases. A 70/30 test-train split of cases with known causes was created and Naïve Bayes (NB), Logistic Regression (LR), Random Forest (RF), K-Nearest Neighbors (KNN), Support Vector Classifier (SVC), and a Gradient Boosting Machine (GBM) were employed using 10-fold cross validation to identify causes of encephalitis. An ensemble approach was employed using the most accurate of these models to create a diagnostic tool. Variables of significance were noted. This tool was then applied to those cases lacking known causes to help identify the relative roles of infectious disease versus autoimmune causes in encephalitis. Finally, an unsupervised approach based on hierarchical clustering was used to separate cases of encephalitis into broad clusters of disease.

Results: The median accuracy of these models was 91% in the supervised dataset. The four most accurate models were combined into an ensemble offering high accuracy for most instances. All four of these models selected largely similar variables as those of highest importance for prediction, evenly split between clinical and sociodemographic/ecologic variables. When applied to the unknown cases, the vast majority were suggested to be caused by infectious agents. Unsupervised learning identified three large clusters of encephalitis. One of these clusters in particular was comprised exclusively of cases with perfect agreement (4/4 models predicting infection).

Discussion: Accurate supervised machine learning models can be created for the classification of encephalitis. The ensemble created will provide an invaluable clinical tool that should help prevent errors in clinical treatment, allow more rapid identification of causal agents and thus initiation of appropriate therapy, and support low resource areas by removing the need for 100+ agent testing capacity. The identification of most encephalitis cases lacking a definitive diagnosis as infectious is remarkable, and unexpected as the majority of newly identified causes of encephalitis in the past two decades have been autoimmune. The use of the unsupervised model in conjunction with the ensemble approach to identify an exclusively infectious cluster will guide future discovery studies, and a proposal for shotgun metagenomic approaches to facilitate these studies targeting those that fit in the exclusively infectious cluster is under consideration.



Ken Fowler

Chief Operating and Information Security Officer, The Cybersecurity Manufacturing Innovation Institute

Ken Fowler is a nationally recognized cyber secure scientist and engineer with a unique and impressive background with multiple levels of expertise including intelligence community operations; military intelligence and operations; global and cultural competence; operations management and process improvement. Prior to joining CyManII, he served as the Chief of Special Access Research, Chief at the Intelligence Surveillance Reconnaissance (ISR) Office, and Technical Director for the NSA office in Texas. Most recently, he holds experience as the Director of Engineering Cyber Solutions at Raytheon Technologies, an aerospace and defense company that provides advanced systems and services for commercial, military and government customers worldwide.

Next Generation Cybersecure Architectures Enable U.S. Manufacturing Innovation, Resilience, and Productivity

Cyber attacks are at an all-time high. Manufacturers are at significant risk as they are the targets through multiple threat vectors. As the manufacturing supply chain races to digitize their systems, they often unknowingly open themselves up to new vulnerabilities in their IT and OT systems. Bad actors have found multiple ways to infiltrate company data to create havoc, potentially costing companies millions of dollars. Attackers can hold operations hostage, impact quality, and damage product life cycles. To protect their people, processes, and technologies, companies must go beyond surface-based cybersecurity and harden their systems to be secure-by-design.

CyManII is the future state of cybersecurity. We connect cybersecurity and energy efficiency to create manufacturing solutions that keep America's companies competitive and protected.

CyManII's intelligent transformation is critical if the United States is to be the global leader in manufacturing. Combining physical, cyber, and energy layers in legacy and new systems of manufacturing, this intelligent transformation requires starting with an Energy Efficient (ε) Pervasive, Unobtrusive, Resilient, and Economical (ε-PURE) secure manufacturing architecture. Linking these secure manufacturing architectures to increases in overall equipment energy efficiency, CyManII provides manufacturers more productivity and more profit. CyManII's secure manufacturing architectures reduce the time to making quality parts – reducing initial scrap parts and generating more profit. Hence, CyManII makes a company more robust (protecting systems and machines from cyber-attacks) and resilient (faster recovery after a cyber breach).

Through our six institutional foundational tasks (IFTs), CyManII is on the path toward establishing expectations for quality security that will be followed and highly respected by OEMs, SMMs, OTs and integrators to help them achieve secure energy savings by overcoming common barriers and re-establish the United States' as a proactive global innovator for manufacturing, cybersecurity and energy efficiency; attaining cyber innovation to secure U.S. manufacturing.



James Gooch

Dr. James Gooch is a UK Intelligence Community Research Fellow at King's College London who specialises in the development of molecular biosensors for forensics, security, and biomedical applications.

James obtained his PhD from King's in 2018 with a project on fluorescent biosensors for the detection of body fluids at crime scenes for which he was awarded both the Royal Society of Chemistry's Geoffrey Phillips Award for Analytical Science and an Elsevier 'Outstanding PhD Thesis' prize.

He has previously conducted postdoctoral research projects funded by the Metropolitan Police Service and the Engineering and Physical Sciences Research Council (EPSRC) on novel methods for the characterisation of biological trace evidence. His current fellowship work focuses on the development and testing of a novel biosensor for the remote detection of nerve agents, a highly toxic group of compounds used in chemical warfare and terrorist attacks. He has also recently secured a grant from UK Research and Innovation (UKRI) to help design a sensor for the detection of the SARS-CoV-2 virus on surfaces.

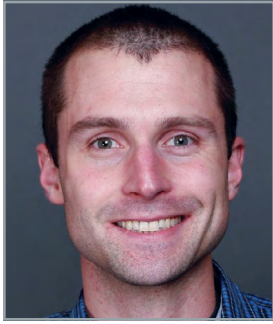
James holds a Postgraduate Certificate in Academic Practice in Higher Education (PGCAPHE) and is a Fellow of the Higher Education Academy. He is also the founder of Elementary Forensics, a STEM outreach organisation that gives forensic science workshops in schools, universities, and museums.

Multiplex Aptamer Biosensors for the Standoff Detection of Nerve Agents

Nerve agents are a highly toxic group of compounds that can cause severe respiratory depression, coma and even death through the disruption of normal nervous function. The use of Novichok in the 2018 attempted political assassination of Sergei and Yulia Skripal on UK soil has reignited concerns around the deliberate use of nerve agents within chemical warfare and terrorist attacks. As a result, significant efforts have been made in the last three years to develop new methods for the detection of nerve agents that are able to overcome the limitations of classical instrument-based techniques (such as low portability, high false-positive rates and an inability to monitor samples from a distance). Recent work has shown that biosensors, a group of molecules able to generate a measurable signal in response to an invisible biological interaction, may be able to overcome these challenges by offering the sensitive, specific and real time analysis of nerve agents without the need for additional specialist equipment.

The overarching aim of this project is to develop and test a multiplex fluorescent biosensor for the detection of two simulated nerve agents: DMMP and Malathion (research analogues for Sarin and VX, respectively). The proposed sensor complex is comprised of two separate DMMP and Malathion-specific aptamers, short sequences of single-stranded DNA that can be produced artificially to bind to any desired target, that simultaneously conjugated to the surface of a gold nanoparticle. Complementary 'flare' reporter DNA strands are also hybridised to these aptamers, each labelled with a fluorescent dye, which are used to generate positive sensor emission signals.

Once successfully constructed and optimised, the performance of this sensor against nerve agent simulants deposited on different surfaces, as well as from different distances through aerosolised spray dispersal, will be assessed. Lastly, studies will be conducted to examine whether the ability of the biosensor to detect nerve agent targets is affected by chemicals that are known to cause 'false-positive' signals within traditional instrumental analysis methods (such as household products, pesticides and herbicides).



Dodd Gray

Dr. Dodd Gray is an Intelligence Community 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.

Inverse Design of Waveguide Dispersion for Broadband Nonlinear Optics

The complexity of chromatic dispersion engineering limits the compatibility of femtosecond-pulsed and broadly tunable laser sources with integrated photonic platforms. Consideration of wavelength-dependent phase and group delays in addition to conventional performance metrics such as loss makes broadband design problems inherently more complex than those for conventional narrowband devices. It follows that more complex geometries optimized using numerous free parameters will generally be needed for broadband applications, likely beyond the reach of intuitive approaches and unlikely to generalize across waveguide platforms, wavelengths, etc.

Design approaches based on sensitivity analysis and machine learning have recently gained popularity in the integrated photonics community. Despite the availability of several adjoint-field sensitivity analysis tools for scattering problems, analogous tools for eigenmode solvers lack the performance needed for 3D modeling and features such as anisotropic and dispersive material models. Nonetheless material dispersion and anisotropy play key roles in many nanophotonic nonlinear waveguides and 3D models are needed to leverage “top-down” patterning for waveguide dispersion optimization in the presence of common features such as multi-layer stacks, partial etching and angled sidewalls.

In this talk I will present an “inverse design” dispersion engineering approach based on a differentiable eigenmode solver for waveguides composed of dispersive and anisotropic materials. The waveguide dispersion model and optimization performance is benchmarked against experiments for second-harmonic generation in thin-film LiNbO_3 waveguides. I will present ongoing work fabricating and characterizing these dispersion-engineered waveguides and discuss their application to integration of stabilized optical frequency combs.



Howard Grimes

Chief Executive Officer, The Cybersecurity Manufacturing Innovation Institute

Dr. Howard Grimes is a noted research scientist and author with 25 years of success in directing complex university and National Laboratory research programs and entrepreneurial start-up initiatives. Currently, he also serves as the Associate Vice Provost and Vice President for Institutional Initiatives at UTSA. Previously, he was Director for Innovation and Industry Partnerships (3 years) at INL's Idaho CAES.

Next Generation Cybersecure Architectures Enable U.S. Manufacturing Innovation, Resilience, and Productivity

Cyber attacks are at an all-time high. Manufacturers are at significant risk as they are the targets through multiple threat vectors. As the manufacturing supply chain races to digitize their systems, they often unknowingly open themselves up to new vulnerabilities in their IT and OT systems. Bad actors have found multiple ways to infiltrate company data to create havoc, potentially costing companies millions of dollars. Attackers can hold operations hostage, impact quality, and damage product life cycles. To protect their people, processes, and technologies, companies must go beyond surface-based cybersecurity and harden their systems to be secure-by-design.

CyManII is the future state of cybersecurity. We connect cybersecurity and energy efficiency to create manufacturing solutions that keep America's companies competitive and protected.

CyManII's intelligent transformation is critical if the United States is to be the global leader in manufacturing. Combining physical, cyber, and energy layers in legacy and new systems of manufacturing, this intelligent transformation requires starting with an Energy Efficient (ε) Pervasive, Unobtrusive, Resilient, and Economical (ε-PURE) secure manufacturing architecture. Linking these secure manufacturing architectures to increases in overall equipment energy efficiency, CyManII provides manufacturers more productivity and more profit. CyManII's secure manufacturing architectures reduce the time to making quality parts – reducing initial scrap parts and generating more profit. Hence, CyManII makes a company more robust (protecting systems and machines from cyber-attacks) and resilient (faster recovery after a cyber breach).

Through our six institutional foundational tasks (IFTs), CyManII is on the path toward establishing expectations for quality security that will be followed and highly respected by OEMs, SMMs, OTs and integrators to help them achieve secure energy savings by overcoming common barriers and re-establish the United States' as a proactive global innovator for manufacturing, cybersecurity and energy efficiency; attaining cyber innovation to secure U.S. manufacturing.



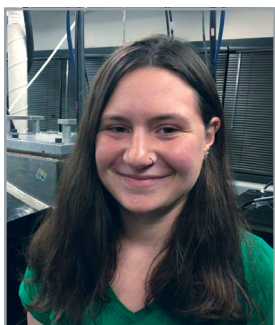
Jason Gross

Dr. Jason Gross is an Associate Professor and Associate Chair for research within the 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. 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 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, outstanding research, and new researcher of the year awards.

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

We summarize our latest findings on a 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 past project years, we integrated and tested UAV and UGV sensor systems, developed and tested a GPS-denied localization approach for a UAV with respect to a UGV, and developed and tested a way-point planning algorithm to balance the mission's exploration criterion while reducing the localization uncertainty of the UAV. Over the past project year, we have modified and tested our GPS-denied localization algorithm to allow for simultaneous motion of the UAV and UGV. We have also improved our planning algorithm to account by learning environmental conditions that may lead to outlier or missing localization measurements with Gaussian process regression. We will present our latest results for both localization and planning.



Carolyn Gunthardt

Dr. Carolyn Gunthardt is an IC Postdoctoral Fellow working at the University of Michigan studying two-photon absorption of entangled photons. Carolyn received her B.S. in chemistry from the University of Washington. She received her PhD from Texas A&M University where she studied the photodissociation of small molecules, including ozone. Her current research involves exciting and imaging biomolecules using extremely low fluxes of entangled photons.

Two-Photon Excitation with Classical and Entangled Light

Entangled two-photon absorption (ETPA) has the potential to be utilized in sensing, imaging, and novel spectroscopic techniques. In order to take full advantage of this potential, preliminary experiments must be performed to determine the structure function relationships involved in ETPA. Experiments probing organic molecules using both classical and entangled TPA have been performed and are key to understanding the similarities and differences between the two processes. The extent of ETPA in a molecule can be quantified using the ETPA cross section, which is determined via transmission based measurements. Experiments have also detected fluorescence from molecules excited via ETPA. A home built fluorescence scanning microscope utilizing entangled light has been developed and used to image thin films of organic samples.



Junyi Guo

Dr. Junyi Guo is a Senior Research Scientist, Division of Geodetic Science, School of Earth Sciences, The Ohio State University. He holds a Bachelor of Engineering degree in geodesy from the Wuhan Technical University of Surveying and Mapping, China, and a Doctor of Science degree from the Catholic University of Louvain, Belgium. His expertise is in theoretical global geodynamics and geodesy.

Improved Modelling of Gravity Variations Associated with Mass Transfers in the Earth System and Body Tide for More Precise Corrections of Gravity Measurements

Co-I: C.K. Shum, Ohio State University.

Modelling of the Earth's static gravity field, with products such as the Earth Gravitational Model EGM2008, is one of NGA's long lasting programs, and relies heavily on data of gravity measurements worldwide, with the time-varying part removed. For real time applications, models of the time-varying part of the gravity field should be predicted based on models of the geophysical system concerned.

With the development of a new type of absolute gravimeter based on atom interferometer and optomechanics attaining sub-micro-gal level accuracy, which is extremely advantageous in transportability and stability, the modeling and interpretation of the Earth gravity field is now at the dawn of a new era. This requires the modeling of the Earth system with an accuracy consistent with that of gravity measurements.

This proposed research aims at providing more accurate geophysical models and computational algorithms for the time-varying gravity, which can be used to correct the gravity measurements for modelling the EGM2008-like static gravity field, or to predict the time-varying gravity in real-time applications.

The content of the research consists of (1) the implementation of an elastic loading theory of the Earth with the lateral heterogeneity considered, which is an advance as compared to the current theory based on a spherically symmetrical Earth model, and (2) the development of an algorithm to evaluate the time-varying gravity at instrument position due to mass transfer in the atmosphere-hydrosphere-cryosphere system. The effect of the heterogeneity on Earth's body tide is also to be estimated, which complements the current theory based on an ellipsoidal Earth model.

The outcome of the research will be detailed theories and algorithms for more accurately computing the time-variable gravity as a result of the loading of mass transfer in the atmosphere-hydrosphere-cryosphere system, together with the Earth's body tide. The improvement in these theories and algorithms is expected to fulfil the need to achieve the full potential of the gravity data collected in the future using the new type of absolute gravimeter based on atom interferometer and optomechanics.

The result will hopefully lead to improve the modeling of both the static and time-varying gravity field of the Earth, which is NGA's long lasting program. It is evident that this research will contribute to NGA's following GEOINT research areas: Advancing Geolocation and data uncertainty; Spatial-temporal analysis; Exploring Data from New Sources and Sensors; Earth, Ocean and Atmospheric Sciences supporting GEOINT.



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 an Associate Professor of Aerospace Engineering and the PI of the Laboratory of Space Systems and Optomechanics (LASSO) at Texas A&M University. His research group is a member of the LIGO Scientific Collaboration and the LISA Consortium. He obtained a Ph.D. in Physics from the Max Planck Institute for Gravitational Physics, where he worked 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.

Optomechanical Gravimeters and Gravity Gradiometers

Authors: Felipe Guzman, Adam Hines, 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 our progress in the development of these technologies and our most recent laboratory results.



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. Dr. Hartzell'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, or 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 measured 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 in on propagating lidar sensor uncertainty into DSM models. The work propagates lidar sensor uncertainties into 3D covariance matrices for each point in a point cloud, and then further propagates these estimated errors into a DSM by way of a triangulated irregular network interpolation method. In addition to sensor uncertainty error sources, we also explore the influence of local terrain roughness and data density on the DSM uncertainty. A technique for estimating point cloud 3D registration uncertainty exclusively from spatial information, i.e., per-point uncertainties are not available, will also be presented. Future work will explore additional methods for estimating DSM model uncertainties through classical error propagation methods, empirical relationships, and simple machine learning methods applicable to multiple terrain types. The developed algorithms will be refactored and made publicly available under an open-source license for use by the geospatial community.



Michael Hayes

Dr. Michael Hayes is a Professor in the School of Natural Resources at the University of Nebraska-Lincoln. He arrived at UNL's National Drought Mitigation Center when it formed in 1995 and became the NDMC's Director in 2007. In October 2016, he transitioned into his current role where he now coordinates the Applied Climate Science major and teaches three climate-related courses. His main research interests deal with drought risk management, climate- and water-related issues. Dr. Hayes received a Bachelors Degree in Meteorology from the University of Wisconsin-Madison, and his Masters and Doctoral

Degrees in Atmospheric Sciences from the University of Missouri-Columbia.

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 near future.



Stephan Hlohowskyj

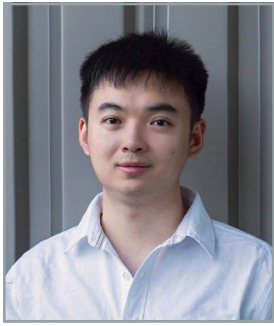
Dr. Stephan Hlohowskyj is a post-doctoral scientist with Oak Ridge Institute for Science and Education (ORISE) conducting explosives research at the Federal Bureau of Investigation (FBI) in the Research Scientific Unit (RSU). He is currently embedded with the Explosives Unit (EU) at the Terrorist Explosive Device Analytical Center (TEDAC), Huntsville, Alabama. He is a geochemist by training, receiving his B.S. from University Nevada, Las Vegas in 2005 in geology, and his M.S. from the University of California, Riverside in soil and water science in 2008. He recently received his Ph.D. from Central

Michigan University in Geochemistry in 2020. His dissertation research focused on identifying 'non-traditional' isotopes and redox sensitive trace elements in ancient rocks. Over the past year he has been working on a source attribution project supported in part by the Defense Threat Reduction Agency (DTRA) on energetic materials using stable isotope ratio mass spectrometry (IRMS).

Attribution of Explosives and Explosive Precursors

Explosives are a continuing threat to public safety due to international and domestic terrorist activities. Further, with information easily available on the internet anyone can learn to create improvised bombs using simple household chemicals. To combat this hazard, the FBI has been tasked as the premiere law enforcement agency in the United States to identify and stop explosive related terrorists' attacks on the public. This work often involves forensic examinations of explosive evidence either before or after an attack is attempted. These examinations help determine the presence and type of energetic material, while also identifying precursor chemicals and/or post-blast residues. Any unknown chemicals are identified through comparison to an explosive reference library of known flammable liquids, primary explosives, acids, bases, fuels, and oxidizers. This approach is highly effective for a wide number of cases investigated by the FBI. Furthermore, identifying explosives, precursor chemicals, and manufacturing processes can supply information to help trace explosives to back to their origin *via* source attribution. However, when examining chemically identical materials or compounds discrimination between explosives becomes very difficult. This problem can occur when investigating of multiple, possibly related, attacks or terrorist networks using a clandestine lab or bomb making method.

The need to understand the source of chemicals used in explosives and the method used to make them is paramount, since this knowledge can provide investigative leads to specific terrorists and help with interdiction of precursor chemicals used. Isotope ratio mass spectrometry directly addresses the difficulties with forensic examinations of chemically identical materials. The isotopic signature of a material can be highly influenced by specific chemical processes used to manufacture explosives, precursor chemicals, and even the starting or feedstock materials. For explosives the stable isotopes of carbon (C), oxygen (O), hydrogen (H), and nitrogen (N) often provide unique enough signatures to discriminate between chemically identical materials. Using this framework, we present preliminary research on; 1) the creation of a isotope reference database of explosive materials and precursor chemicals, 2) a pathway to validation for IRMS methodology to be used in the US legal system, and 3) the current analytical capabilities of IRMS in mock example terrorist cases and potential new emerging threats. Our results indicate that chemical insights gained through IRMS not only improve the quality of data gathered by law enforcement, but also have intelligence applications for military partners seeking to mitigate terrorist threats.



Zhiting Hu

Dr. Zhiting Hu is an Assistant Professor in Halicioglu Data Science Institute at UC San Diego and a visiting research scientist at Amazon Alexa AI. He received his Bachelor's degree in Computer Science from Peking University in 2014, and his Ph.D. in Machine Learning from Carnegie Mellon University. His research interests lie in the broad area of machine learning, natural language processing, ML systems, healthcare and other application domains. In particular, He is interested in principles, methodologies, and systems of training AI agents with all types of experiences (data, knowledge, rewards, adversaries, lifelong interplay, etc).

His research was recognized with best demo nomination at ACL2019 and outstanding paper award at ACL2016.

Toward Knowledge and Structure-rich Text Generation

My primary research interests lie in the general areas of Machine Learning, Artificial Intelligence, Natural Language Processing, as well as ML systems, computer vision, healthcare, and other application domains.

In particular, I'm interested in principles and methodologies of training AI agents with ALL types of experiences, ranging from data instances (NeurIPS), structured knowledge (ACL, NeurIPS), constraints, to rewards, adversaries (NeurIPS), lifelong interplay, etc. To this end, I've been studying a standardized ML formalism ("Standard Model" of ML) for systematic understanding, unifying, and generalizing a wide range of ML paradigms (e.g., supervised, unsupervised, active, reinforcement, adversarial, meta, lifelong learning).

On this basis, I develop methods and tools for Composable ML that enables easy composition of ML solutions (Texar, ASYML, as part of the open-source consortium CASL); and rich applications for controllable text generation (ICML) and others.



Rachel Jones

Dr. Rachel Jones works in the Office of Geomatics at National Geospatial-Intelligence Agency and holds a doctorate in Geological Engineering from Missouri University of Science and Technology. The focus of her research used remote sensing methods for groundwater potentiality investigations in post-civil war Uganda. Dr. Jones has worked in numerous humanitarian efforts including victim services, crisis support, counter human trafficking, and counter wildlife trafficking. Her future research is intended to target environmental security and its convergence with refugee movements and illicit trade networks.

A Groundwater Potentiality Investigation of Gulu District, Uganda using Fused Polarimetric Synthetic Aperture Radar and Magnetometry for Lineament Extraction

Developing countries have few resources for ground-based hydrological investigations to determine optimal placement of boreholes for community water access. Remote sensing data are available at a variety of resolutions and sense different parameters, and are useful inputs for hydrologic models, but these data are rarely obtainable in developing countries with the parameters or resolutions necessary for hydrologic applications. This research used existing remote sensing and geographic information system techniques to identify areas of optimal water supply in locations with limited geologic or hydrologic information, such as Gulu District, Uganda. Fusing different remotely sensed data sets can produce higher resolution data sets of some necessary parameters. This research focuses on fusing remotely sensed data sets to aid in the investigation of groundwater resources using a multicriteria decision method. This research used principal component analysis to improve the accuracy and resolution of data products and enhance surface lineaments. This fusion technique was applied to Alos Palsar quad-pol synthetic aperture radar and magnetic data acquired in the Gulu District of Uganda. The resultant lineament maps were used to develop a groundwater potentiality model using the analytical hierarchy process.



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. While working as a Buyer, she also earned an MBA from Georgia Southern University. Juliette received her Ph.D. in Environmental Toxicology from Texas Tech University in the Fall of 2018. 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 hopes to develop carbon nanostructure detection methods for crops by monitoring physiological and molecular responses in maize. She will also explore external factors, like time of day and other varying environmental conditions to optimize detection methods. She will use gene expression measurements, volatile organic compounds, and other monitoring methods to evaluate plant responses to the environment. Through this research project projects, she aims to develop better methods for quantifying and detecting carbon nanomaterials in the environment through plant response.

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

Plants sense and respond to subtle environmental perturbations. The effects of small changes in the environment can be detected through the changes to plant physiology and biochemistry using molecular and imaging analytical techniques. Therefore, plants can be used as a sensor to detect anthropological changes in the environment, including the presence of unwanted chemicals. One chemical class of concern is engineered nanomaterials (ENMs) and in particular, carbon nanostructures. This project investigates using plants to monitor the environment for the presence of carbon nanostructures. The whole plant effects of carbon nanostructures are examined in conventional maize through phenotyping, mass spectrometry, and RNA sequencing. The approach employed monitors 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; both were investigated. 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 from 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. The end goal of this project is to use plants as indicators through monitoring phytochemicals 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 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.

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Despoina Kampouridou

Dr. Despoina Kampouridou was born in Greece, in 1990. She received the Electrical and Computer Engineering degree from Aristotle University of Thessaloniki, Greece, in 2015 and the Ph.D. degree in Electronic, Electrical and Systems Engineering from the University of Birmingham, UK, in 2020.

During 2018 she was a Research Associate, and since 2019 she has been a Research Fellow at the Department of Electrical, Electronic and Systems Engineering at the University of Birmingham, UK. In 2020 she was awarded a Royal Academy of Engineering

UK Intelligence Community Postdoctoral Research Fellowship (2020-2022). Her research interests include analysis and design of metamaterials, leaky-wave antennas, dispersion analysis methods and microwave circuits. She is a member of IEEE and the Technical Chamber of Greece.

Active Non-Foster Ultra-Broadband and Reconfigurable RF/Microwave Metamaterials

Ultra-broadband and reconfigurable metamaterials and antennas will provide a disruptive technology for the development of the next generations of wireless systems for defence as well as civil applications, such as next generation aircraft technology (including unmanned air vehicles), autonomous land vehicles, and new mobile communications networks (beyond 5G and mobile satellite networks). In this project, it is aimed to develop a new design approach for such metamaterial-based antennas with the use of non-Foster elements, spanning from the RF (1 GHz) to the higher mm-wave spectrum (up to 100 GHz). Such non-Foster elements form a promising solution to the bandwidth expansion of the antenna performance. This represents an entirely new design approach for microwave metamaterials and leads to the development of multifunctional antennas with active elements that provide ultra-wideband and reconfigurable operation with high gain performance and agility of the radiated beam shape, direction and polarisation.



John Kerekes

Dr. John Kerekes received the B.S., M.S., and Ph.D. degrees in electrical engineering from Purdue University, West Lafayette, IN in 1983, 1986, and 1989. From 1989 to 2004 he was a Technical Staff member with the Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, MA. Since 2004 he has been a member of the faculty of the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology, Rochester, New York. His research interests include the modeling and analysis of remote sensing system performance in pattern recognition and geophysical parameter retrieval applications. He has served as the Principal Investigator for 40 externally-funded research projects, published over 190 scientific articles and has served as the primary advisor for 18 PhD and 27 MS students. Dr. Kerekes is a Member of Tau Beta Pi, Eta Kappa Nu, the American Geophysical Union, and the American Society for Photogrammetry and Remote Sensing. He is a Senior Member of IEEE, the Optical Society of America, and SPIE. Since 2017 he has been serving as the Chief Financial Officer of the IEEE Geoscience and Remote Sensing Society.

Fundamental Research on Detection and Classification Limits in Spectral Imagery

Satellite and airborne spectral imaging of the earth in the visible through shortwave infrared region of the optical spectrum has been demonstrated to be a unique technology to perform detection and classification of natural materials and man-made objects. This technology relies on the spectral phenomenology of how light reflects and scatters from objects, which is based upon their chemical composition and surface microstructure. The capability to detect specific objects from the background, or to segment areas into semantically meaningful classes, depends not only on the characteristics of the surfaces, but also on the parameters of the imaging sensor, the illumination, the atmosphere, and processing algorithms. As technology of the imaging sensor and processing algorithms improves, it is desirable to explore the fundamental limits of detection and classification inherent in the surface characteristics as a component in the optimal design and operation of spectral imaging systems. Such research will help technologists and operators know the limits of a given imaging system, and identify when further improvements in the technology will not lead to performance improvements due to fundamental phenomenological limitations.

This research is investigating the quantification of fundamental class separability of earth surface materials and objects as observed by a given class of spectral imaging systems. The problem is one of basic science in the spectral characterization of surfaces (including their variability), but is also coupled to the technology of imaging systems and their optimal operation. The outcome of the research will include advances to the basic scientific understanding of the limits to remote spectral sensing together with tools to support an operational capability to acquire and operate spectral imaging systems in an optimal manner.

The project was initiated in July 2021 and is proceeding in a phased approach. The first phase is the development of a computational tool for predicting detection and classification performance of spectral imaging systems. This tool is based on a previously-developed analytical modeling tool which propagates the reflectance statistics of surface materials through the imaging chain. The tool is being developed to be compatible with and validated by Rochester Institute of Technology's Digital Imaging and Remote Sensing Image Generation physics-based image simulation code and will be verified through empirical data collections.

The second phase of the project will be use and enhancement of the computational tool to explore the limits of spectral imaging system to detect and classify surface materials. A range of scenarios will be explored to advance scientific understanding of these limits in practical earth imaging applications.



Michael E. Ketterer

Dr. Michael E. Ketterer obtained his primary and secondary education in Buffalo, New York, 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. Mike has held tenure-track/tenured faculty positions at John Carroll

University, Northern Arizona University, and Metropolitan State University of Denver. He is currently Professor Emeritus of Chemistry and Biochemistry at Northern Arizona University, and recently served as an adjunct instructor in the Chemistry and Biochemistry Department at University of Denver. Michael has taught undergraduate and graduate-level courses in general chemistry, analytical chemistry, and environmental chemistry. Michael is currently an NGA visiting scientist working under the mentorship of Dr. James A. Jordan.

Uranium Isoscapes in Natural Waters: What Factors are Associated with Uranium Concentrations above 30 Micrograms/Liter?

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 . Naturally occurring uranium exhibits relatively consistent, predictable isotope compositions; the $^{238}\text{U}/^{235}\text{U}$ 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 $^{234}\text{U}/^{238}\text{U}$ 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; $^{234}\text{U}/^{238}\text{U}$ ratios may be elevated by as much as tenfold vs. the equilibrium value of 0.000055.

Natural variations in $^{234}\text{U}/^{238}\text{U}$ ratios have been used to examine mixing between multiple water sources. The systematic variation in $^{234}\text{U}/^{238}\text{U}$ 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 may potentially be affected by anthropogenic processes; near many nuclear installations, a local or regional pattern of altered isotope composition is evident from mixing between “enriched” or “depleted” uranium with a background of naturally occurring U. Much 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.

This presentation will summarize how U isoscapes are applicable in evaluating the geospatial patterns arising from natural and anthropogenic effects. As part of the author's Visiting Scientist appointment, we measured U concentrations in 1784 water samples from a broad geographic area; of these, 94 were found to contain U concentrations exceeding 30 micrograms/liter.

The geochemical factors associated with occurrences of $\text{U} > 30$ micrograms/liter will be addressed in the presentation.



Laura Kim

Dr. Laura Kim is currently an Intelligence Community Postdoctoral Fellow in the Quantum Photonics Laboratory at the Massachusetts Institute of Technology. She received her B.S. degree in chemical engineering and Ph.D. degree in materials science, both from California Institute of Technology. She is an EECS Rising Star and a recipient of Gary Malouf Foundation Award and National Science Foundation Graduate Research Fellowship. Her doctoral research focused on understanding photonic-quasiparticle-driven light-matter interactions in low dimensional materials to realize mid-infrared nanophotonics and ultrafast phenomena. Her current research involves developing nanoscale quantum sensing technologies.

Absorption-Based Diamond Quantum Microscopy on Resonant Metasurfaces

Nitrogen vacancy (NV) centers in diamond have emerged as a leading platform for solid-state quantum sensors for a wide range of applications ranging from biomedical devices to geology and navigation devices. A particular area of focus has been on quantum microscopy for wide-field imaging applications, which take advantage of the atomic length scale of the diamond color center. The central challenge remains in maximizing optical signal from the near-surface color centers and optimizing sensitivity per area. Resonant metasurfaces solve this problem by concentrating the optical field with a large overlap with a micron-scale NV layer to mediate efficient spin-photon interactions. I will report quantum sensing metasurfaces (QSMs) consisting of periodic arrays of plasmonic and dielectric nanostructures that readily couple with external radiation and allow shot-noise-limited sensing with a standard camera, eliminating the need of single-photon detectors. The planar sensing surfaces boost 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, I theoretically predict sub-nT Hz^{-1/2} sensitivity per 1- sensing area. In addition, in this presentation, I will report recent progress on experimental demonstration of the QSMs. The projected performance makes the studied QSMs appealing for the most demanding applications such as imaging through scattering tissues and spatially resolved chemical NMR detection.



Justin Knight

Dr. Justin Knight recently graduated from the James C. Wyant College of Optical Sciences with his Ph.D under the supervision of Dr. Olivier Guyon. His dissertation, Complex Mask Coronagraphs for High-Contrast Imaging, is focused on a particular coronagraphic architecture known as the Phase-Induced Amplitude Apodization Complex Mask Coronagraph (PIAACMC), which aims to provide deep contrast and high planetary-light throughput for direct imaging of exoplanets. In particular he developed a tolerancing analysis based on the fabrication of phase-only focal plane masks used in the PIAACMC

architecture for the Subaru Coronagraphic Extreme Adaptive Optics (SCEXAO) instrument at the Subaru telescope in Hawaii. The phase-only focal plane masks were subsequently tested on-sky at SCEXAO where the data showed the first results of a fully functional PIAACMC architecture with respect to ground telescope observation. Currently Justin resides in Tucson, Arizona, working at the University of Arizona as an Intelligence Community Postdoctoral Fellow on the topic of wavefront sensing comparisons for downward imaging satellite using adaptive optics systems to compensate for any degradations to image quality.

Extended Scene Wavefront Sensing Simulation Analysis

Earth-observing satellites are ideally launched with low-weight, large area light-collecting mirrors which produce images containing high-resolution content of extended scenes of interest. To meet the corresponding imaging requirements, satellite system performance must be robust with respect to its operating environment – namely, space. In particular non-uniform thermal stresses in the primary mirror from exposure to temperature fluctuations, often causing the most deleterious effects to image quality by inducing distortions to the mirror shape, must be compensated for by some means. In this research, an adaptive optics (AO) system is considered the error compensatory mechanism on-board a satellite; this is an optical sub-system run in a servo-loop to sense and correct for optical aberrations which adversely affect image quality. Even in an ideal situation where the effects of thermal stresses are completely mitigated, the satellite system must be able to detect light signals with respect to sources of error generated either from the environment itself or incurred over the lifetime operation of the satellite, as well as noise sources inherent to the physical operation of the on-board optics and light detectors. The additional environmental sources of error include the effect of light propagating through the Earth's atmosphere, the degradation of specular efficiency across optics which produces stray light, i.e. light where it should not be by design, and loss of pixels on light detectors from radiation damage. Meanwhile noise sources include detector read and dark noise, as well as signal noise due to the quantum nature of light, i.e. photon noise. The research focus is to quantify the sensitivity of light detection in the AO system, known as wavefront sensing, with respect to these sources of error which fundamentally determine the imaging performance of a satellite system. The most fundamental source of error in any optical system is photon noise – as such, it is the primary topic of consideration with respect to wavefront sensing techniques including the industry standard known as the Shack-Hartmann wavefront sensor (SHWFS), and several other extended scene compatible wavefront sensing modalities. The analysis approach uses physical optics propagation to simulate a satellite system equipped with an AO sub-system to survey the sensitivity of various wavefront sensing techniques to photon noise; this allows one to compute the contribution of this specific error term to a performance metric reflective of total system performance such as rms wavefront error. In turn each of the other aforementioned sources of error will be considered in an aggregate form of analysis to understand the limits of adaptive optics for extended-scene imaging. Ultimately the goal is to verify the derived sensitivities of various down-selected wavefront sensing candidates with laboratory experiments in an effort to determine which, if any, outperform the SHWFS.



Andrew Lamb

Dr. Andrew Lamb is a UK Intelligence community research fellow in Quantum Gravity Sensing at the QT Hub for Sensors and Timing at the University of Birmingham. His Royal Academy of Engineering fellowship focuses on the development of high data-rate quantum gravity sensors for the scanning of cargo as it passes through a port. In addition to this work he leads the Birmingham based work on atom interferometry for moving platform applications, with a Dstl funded PhD student working on enhanced measurement rates for cold atom gravity gradiometry. He also works in partnership with a consortium to develop an atom

interferometer prototype for deployment on a CubeSat for measurements of drag induced by the upper atmosphere.

He has directly contributed to the development of industrial cold atom gravity gradiometer prototypes, constructed in the Innovate UK funded REVEAL and Gravity Pioneer projects. During his PhD, submitted in 2018, he was based at UoB where he worked on the Dstl Gravity Imager Project and. Through this Dstl funded work he developed a prototype of the UK's first field deployable cold atom gravity gradiometer that is the flagship programme of the Sensors and Timing Quantum Technology Hub. Within this work he achieved a patent for the underlying gradiometer design and, as part of the QT Hub, contributed to the outcome of the 2016 Blackett review on quantum technology and has been featured in the Dstl Quantum Technology Landscape 2016.

Gravity Portals: Quantum Sensors for Enhanced Border Screening

Smuggling of contraband across borders poses serious security threats to the UK that, with current technology, cannot always be detected. These illicit materials therefore represent needles within the haystack of legitimate cargo, the flow of which would ideally be left unhindered. Proffered solutions to this technological shortfall would provide sufficient inspection capabilities whilst minimising additional delays, which represent substantial economic loss at scale. This talk will discuss the development of “gravity portals” for use at national borders through the deployment of gravity gradiometers based on cold atom interferometry: providing a remote and passive sensing capability, against which there are no effective countermeasures.

Utilising cold atom gravity gradiometers to construct these portals at points of ingress into the country will allow the continuous scanning of vehicles and cargo, providing a valuable means of detecting contraband. Such portals would provide a new, almost real time, sensing modality with impressive synergies to existing technology, such as improved detection of shielded fissile material that is hidden from existing radiation sensors.

Gravity sensors have not yet been deployed due to the significant measurement times, environmental sensitivity and high single unit costs of existing technology. Cold atom based gravimeters have the potential to overcome all of these issues, with work in the UK Quantum Technology programme addressing all facets of the technological challenges which prevent their widespread deployment. With the QT hub development, supply chain maturation and input from end users the technology will become more readily available and find wider deployment routes in civil, defence and security application areas.

Work within the IC fellowship addresses the need for a better understanding in the use of gravimetry within security focused applications. Primarily this aims at reducing the substantial measurement times required by current quantum gravity sensors in order to form a complete image of local gravity, which substantially prohibits their use in a border control setting. Parallel to sensor development a knowledge transfer is taking place to better understand potential use cases for gravimetry in a security setting. Through application of this environment critical knowledge and high data-rate measurement techniques to a field capable quantum gradiometer system there could be in field demonstrations in the near term.



Luce le Gorrec

Dr. Luce le Gorrec is a UK Intelligence Community Postdoctoral research fellow at the University of Strathclyde, Glasgow. There, since December 2019, Dr. le Gorrec has worked on developing efficient ways to partition large complex networks, under the supervision of Dr Philip Knight, who co-wrote a well-referenced book about networks. This project is a collaboration with DSTL, and has been made possible by the UK IC Postdoctoral Research Fellowship of the Royal Academy of Engineering, from which Dr. le Gorrec was one of the 2019 awardees.

Partitioning mathematical objects was already at the core of Dr. le Gorrec's PhD, that she did in France, under the supervision of Drs Daniel Ruiz and Sandrine Mouysset. Indeed, from 2016 to 2019, Dr. le Gorrec worked to conceive an algorithm to partition matrices, with diverse applications, such as accelerating the resolution of linear equation solvers, finding the kind of actions labelling extracts of online exchanges, and foremost, already, partitioning networks into meaningful blocks.

Prior to this, Dr. le Gorrec studied to obtain an engineer master degree in computer sciences and applied mathematics. This is when she developed a strong taste for designing mathematical solutions and algorithms to answer real-world problems, and for implementing such solutions into software.

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 partition large directed complex networks into meaningful blocks. Although partitioning undirected networks is a classical problem that has been widely investigated, partitioning directed networks is a much more challenging issue, far less studied, mainly because the definition of a meaningful block is strongly application dependant.

Recently, higher-order representation of networks has emerged as an effective tool in diverse applications, among which graph partitioning. The higher-order representation is typically built on small induced subgraphs, called graphlets or motifs, and that have been identified as “building blocks” that can be used to uncover key properties of networks.

Working on motifs presents advantages: these are mesoscopic features of the networks, and thus may be used to express some complex notions within networks. Furthermore, the higher-order representation provided by a motif is an undirected network whether or not the original one is directed or undirected. Hence, by choosing motifs that convey the notion of meaningful blocks in the network to partition, it enables one to apply, on the higher-order representation, tools designed for undirected networks for which there is a much better established body of work than for the directed case.

We note that recent initial research about using motifs for community detection shows real promise that worth to be expanded upon.



Jon Lewis

Jon Lewis is a Research Fellow at the Program on Extremism, where he studies the evolution of white supremacist and anti-government movements in the United States and federal responses to the threat. He is an Investigator with the National Counterterrorism Innovation, Technology, and Education Center (NCITE), and provides assistance for The ISIS Files Project as well as the Program's partnership with the Global Network on Extremism and Technology (GNET). Jon also provides policy support for PoE's partners in the Congressional Counter-Terrorism Caucus, the leading bipartisan voice in Congress

for pragmatic approaches to tackling extremism and radicalization. His research has been featured in several academic and popular publications, including the *CTC Sentinel*, *The Washington Post*, and *Lawfare*. Before joining the Program on Extremism, he worked as a research assistant at the International Institute for Counterterrorism (ICT) and the Combating Terrorism Center at West Point (CTC). Jon Lewis holds a Masters in Homeland Security Policy from Rider University.

Analyzing Digital Footprints of January 6th Capitol Hill Rioters

Well over 500 individuals have been charged in the United States District Court for the District of Columbia for their alleged participation in the attack on the Capitol Hill building on January 6th. A free, online database maintained by The Program on Extremism at George Washington University serves as a centralized source for court records related to these legal proceedings. Such documents provide an invaluable resource for understanding the heterogeneous psychosocial dynamics of charged participants. Within the corpus of court records emerge distinct groups of alleged Capitol Hill Siege participants: From members of extremist movements like the Oath Keepers, Proud Boys, and Boogaloo movement, to adherents of the amorphous QAnon conspiracy, and even more individuals without clear group or movement affiliations. Crucially, the majority of cases brought by federal prosecutors involve incriminating evidence from individuals' personal social media accounts, or those of others in their social networks, in addition to other digital evidence. These digital footprints left by individuals who were present at the Capitol attack offer insights into their behaviors, perceptions, motivations, and experiences from before, during, and after the events on January 6th. Our research analyzes these digital footprints through an in-depth assessment of the prevalence of self-incrimination and analyses related to participants' use of social media as prosecutorial evidence, the role of tips as a central evidentiary points, and what lessons can be learned from January 6th when examining the landscape of domestic violent extremism in the United States.



Lia Ying Li

Dr. Lia Ying 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 Sensing: Why So Sensitive?

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. 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. Due to the lack of laboratory access during the pandemic, in this talk I will focus on the theory behind optomechanical sensors and strategies to increase the optomechanical coupling which boosts the signal to noise readout. Using Fisher information analysis, I will show how to extract optimum sensing parameters and the quantum advantage you can obtain by using quantum states of light to perform optomechanical measurements.



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. In 2019, she served as a Research Associate for the University of Tennessee, working in residence at ATDD to characterize and predict the emission of reactive nitrogen compounds over coastal ecosystems using measurements and modeling approaches. Dr. Lichiheb has several teaching and supervision experiences, and she is a member of the American Geophysical Union.

Improving the Prediction of Hazardous Material Dispersion in an Urban Environment

Concerns about the consequences of intentional and adversarial releases of hazardous materials and the emissions from industrialization and traffic have resulted in a growing level of research focused on dispersion in urban areas. Several dispersion models have been developed to analyze and predict the transport and dispersion of hazardous contaminants, and they usually rely on meteorological information obtained from the meteorological models of NOAA's National Weather Service (NWS). In this context, it has been shown that classical meteorological models from the NWS provide an inadequate basis for atmospheric dispersion forecasts in Washington, D.C. In recognition of this deficiency, a program called DCNet was established by NOAA in 2003 to collect a large data base of meteorological measurements in Washington, D.C. The goal of DCNet has been the provision of real-time meteorological observations over Washington, D.C. to support the use of atmospheric transport and diffusion models as well as to improve the prediction of the weather affecting residents. The DCNet data represent a large, relatively uniform urban city covering a broad spectrum of weather conditions, which permits an unparalleled description of atmospheric flow behavior over this type of terrain.

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. Currently, we are comparing observations of the DCNet station on the U.S. Department of Commerce Herbert C. Hoover Building against the North American Mesoscale (NAM) model outputs for the period 2017-2019, focusing mainly on the wind speed and wind direction data. The goal is to develop a simple methodology for modifying NAM outputs so that the dispersion requirements of the city and its urban area can be satisfied. This methodology will allow us to quantify the prediction errors of NAM model and propose adjustments of key variables controlling dispersion model calculation. The next step will be to implement those adjustments in a dispersion model of widespread use. As a starting point, the NOAA HYSPLIT dispersion model will be used.



Lori Magruder

Dr. Lori Magruder is an Associate Professor in the Aerospace Engineering Department at the University of Texas at Austin and is a subject matter expert in altimetry, remote sensing and 3D geospatial data exploitation. Dr. Magruder received her bachelor's degree from The University of Southern California in Aerospace Engineering and her master's degree from Princeton University in Mechanical and Aerospace Engineering. Her Ph.D. was earned from The University of Texas at Austin with a focus on ground-based validation studies for NASA's ICESat mission. She has held positions at Jet Propulsion Laboratory and The Johns

Hopkins Applied Physics Laboratory prior to returning to UT Austin. Dr. Magruder was selected to be the ICESat-2 Science Definition Team Leader in 2014 to support mission development and early on-orbit satellite operations. She also is the principal investigator for the satellite's precision pointing determination operational program and geolocation validation studies. In 2020 Dr. Magruder was selected by NASA to lead the ICESat-2 Science Team. Dr. Magruder leads many other NASA research efforts in addition to supporting programs through the Department of Defense with her expertise in geospatial topics and the unique link she brings between engineering and science applications through remote sensing.

An Automated Terrain Model Correction Strategy using Icesat-2 for Global Geospatial Applications

The most prevalent global surface models are derived from space-based technologies but primarily radar systems. These systems often have the advantage of broad spatial coverage and low latency for repeat measurements. However, these systems are less advantageous in the most challenging environments. Radar derived digital surface model accuracies are often less in vegetated regions, as the wavelengths associated with radar mapping missions do not fully penetrate the canopy. Elevation errors are also substantial over dynamic topography. Correction models using airborne lidar reference datasets can be effective for localized studies to improve the terrain products but often the data is not readily available or seasonally/temporally irrelevant. Moreover, the correction models are not currently applicable to larger scale studies despite the global observations of the radar missions (e.g. SRTM, TanDEM-X). This presentation highlights an automated method for correcting digital terrain models derived from radar elevation products using NASA's newest Earth observing laser altimeter, the Ice, Cloud and Land Elevation Satellite-2 (ICESat-2). ICESat-2 elevations, in concert with Landsat 8 (global imagery), create a model based correction strategy for the radar derived elevations using geographically correlated canopy cover and surface slope information. The results are validated at the study site using high-resolution, high fidelity airborne lidar datasets as a reference surface. The application of the correction model on the radar measurements results in nearly 50% improvement in elevation accuracy for this region. Additionally this established proof of concept provides a starting point for further research in how this method, with ICESat-2 data, can be extended to other environmental regions, other radar or image derived elevation products and inform future techniques for similar application at the global scale.



Manoranjan Majji

Dr. Manoranjan Majji is an associate 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 Pattern Recognition and Sensor Fusion for Alternative Positioning Applications

Sensor technologies and approaches for alternative positioning, navigation and timing that use geospatial intelligence such as the Earth's magnetic field 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. Recent advances in sparse and dense pattern recognition techniques used for registering geomagnetic signals 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.

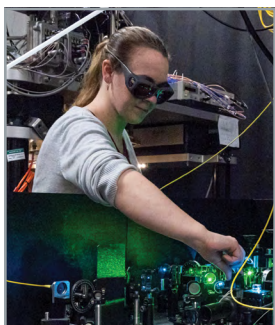


Panos P. Markopoulos

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 then, he has been an Assistant Professor (2015-2021) and an Associate Professor (2021-present) of electrical engineering at the Rochester Institute of Technology (RIT), Rochester, NY, USA, where he directs the Machine Learning Optimization and Signal Processing Laboratory (MILOS LAB). He is also a Core Faculty of the RIT Center for Human-Aware Artificial Intelligence. In 2018, 2020, and 2021 he was a Summer Visiting Research Faculty with the U.S. Air Force Research Laboratory, Information Directorate, in Rome, NY, USA. He has co-authored more than 65 journal and conference articles in areas of statistical signal processing, machine learning, data analysis, optimization, and communications, with a current focus on tensor methods, efficient neural networks, robustness, Lp-norm formulations, and dynamic learning. He has been PI and Co-PI of multiple research projects funded by the U.S. National Science Foundation, the U.S. National Geospatial-Intelligence Agency, and the U.S. Air Force Research Laboratory. In 2020, he was the recipient of the the prestigious AFOSR Young Investigator Award. He is a Member of the IEEE Signal Processing, Computer, and Communications Societies, with high service activity that includes the organization of multiple conference events, such as the 2019 IEEE International Workshop on Machine Learning for Signal Processing, the 2019–2021 versions of the SPIE DCS Conference on Big Data: Learning Analytics and Applications, and the 2017–2021 versions of the IEEE International Workshop on Wireless Communications and Networking in Extreme Environments.

Tensor-Based Parametrization of Object Detection CNNs and Application to Aerial Imagery

Detection CNN architectures often exhibit over-parameterization which results in excessive computational and storage overhead (making them impractical for edge deployment), but also undesired over-fitting and reduced performance. In this work, we focus on state-of-the-art CNNs for target detection in remote sensing imagery and counteract over-parameterization by enforcing a low-rank tensor structure to the trainable parameters. This way, we show that we can adjust the number of parameters to the levels justified by the training dataset at hand, to maximize performance. Importantly, this network capacity tuning is performed without changing the network architecture (e.g., number of layers or number of channels per layer). Our numerical studies show that the proposed network, with low-rank tensor parameters, attains superior detection performance, with storage savings as high as 70%. In our future research, we will focus on extending this design for the fusion of multiple imagery modalities, so that we further improve the network's detection performance. This can be accomplished through joint low-rank tensor decompositions of the learning parameters of parallel network streams (one per modality).



Claire Marvinney

Dr. Claire Marvinney is an Intelligence Community Postdoctoral Fellow working at Oak Ridge National Laboratory in the Quantum Heterostructures Group under the direction of Benjamin Lawrie, having begun her work at the lab in the Quantum Information Science Group. At ORNL, she has been integral to the development of a millikelvin optical microscopy system and to the study of superconducting devices and quantum materials at cryogenic temperatures. Claire received her Ph.D. from Vanderbilt University in the spring of 2018 under the direction of Richard Haglund for the study of optical properties of ZnO

nanostructures. During her Ph.D., Claire was chosen for the NSF East Asia and Pacific Summer Institute where she did a summer of research at Northeast Normal University in Jilin Province, China. After receiving her PhD, she worked with Josh Caldwell at Vanderbilt University studying the mid-infrared optical properties of semiconducting materials. Outside of research, Claire volunteers within the scientific community, including as the social chair for the Oak Ridge Postdoctoral Association (ORPA) from 2019-2020, a volunteer organizer and moderator for the 2020 ORPA Research Symposium, and now as a member of the Quantum Science Center's (QSC) Postdoc and Graduate Student Association where she has helped to organize and moderate poster sessions and seminars.

Quantum Sensing at Millikelvin Temperatures

Single photon detection is essential to fundamental tests of quantum mechanics and entanglement distribution and to applications in quantum networking, quantum computing, and quantum sensing. Superconducting nanowire single photon detectors (SNSPDs) offer high-timing-resolution, high-quantum-efficiency, and low-dark-count-rate operation for visible to infrared wavelengths. 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. In a growing number of cases, large magnetic fields are being incorporated into quantum microscopes, nanophotonic devices, and sensors for nuclear and high-energy physics that rely on SNSPDs, but superconducting devices generally operate poorly in large magnetic fields. Additional research is still needed to better understand the behavior of superconducting nanowires and other quantum devices at the mesoscale and in large fields.

In this talk, I will demonstrate i) position sensitivity to the signal readout pulse of large area SNSPDs that is consistent with a simple model of microwave propagation along the length of the nanowire. 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 and may enable improved dark count filtering. ii) SNSPDs can operate robustly under large magnetic fields and have the potential to be used as a multifunctional quantum sensor capable of describing the temperature and magnetic field on-chip simply by varying the bias current to change the operating modality from single photon detection to thermometry or magnetometry. iii) The development of a scanning confocal optical microscope in a dilution refrigerator equipped with a 6, 1, 1, T vector magnetic field enables the combination of position-dependent and field-dependent studies of quantum materials and devices, which will lead to, among other experiments, the improved understanding of the constraints on SNSPD device operation from the microscopic to device scale.



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”, 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 and cultural heritage imaging.

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 our results from developing a novel, learning framework for sharpening of both Visible-Near Infrared HSI, as well as an extension to the Shortwave Infrared. Additionally, we will present results showing how spatial - spectral structure in the image impacts the ability to accurately sharpen the image. Both results will be presented within the contexts of two common hyperspectral analysis tasks, target detection and classification. This research is sponsored by an NGA University Research Initiative.



Andrew Mines

Andrew Mines is a Research Fellow at the Program on Extremism, where he researches terrorist and extremist behavior and helps lead PoE's efforts on the Capitol Hill Siege database. He is the audio editor for the podcast *Mosul and the Islamic State*, an Investigator with the National Counterterrorism Innovation, Technology, and Education Center (NCITE), and contributes to PoE's partnership with the Global Network on Extremism and Technology (GNET). Andrew also studies the Islamic State's "Khorasan Province" in the Afghanistan-Pakistan region (ISK), focusing on state-led counterterrorism and counterinsurgency operations against the group. He is a graduate of The University of Chicago, and is currently pursuing a Master of Arts in Forensic Psychology at The George Washington University. He has published opinion pieces in multiple outlets including the Washington Post, Lawfare, the CTC Sentinel, Just Security, and GNET, and has provided TV and radio commentary for various affiliates at ABC, CBS, Fox, NBC, and other news outlets.

Analyzing Digital Footprints of January 6th Capitol Hill Rioters

Well over 500 individuals have been charged in the United States District Court for the District of Columbia for their alleged participation in the attack on the Capitol Hill building on January 6th. A free, online database maintained by The Program on Extremism at George Washington University serves as a centralized source for court records related to these legal proceedings. Such documents provide an invaluable resource for understanding the heterogeneous psychosocial dynamics of charged participants. Within the corpus of court records emerge distinct groups of alleged Capitol Hill Siege participants: From members of extremist movements like the Oath Keepers, Proud Boys, and Boogaloo movement, to adherents of the amorphous QAnon conspiracy, and even more individuals without clear group or movement affiliations. Crucially, the majority of cases brought by federal prosecutors involve incriminating evidence from individuals' personal social media accounts, or those of others in their social networks, in addition to other digital evidence. These digital footprints left by individuals who were present at the Capitol attack offer insights into their behaviors, perceptions, motivations, and experiences from before, during, and after the events on January 6th. Our research analyzes these digital footprints through an in-depth assessment of the prevalence of self-incrimination and analyses related to participants' use of social media as prosecutorial evidence, the role of tips as a central evidentiary points, and what lessons can be learned from January 6th when examining the landscape of domestic violent extremism in the United States.



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. She will continue this research as an Assistant Professor of Electrical and Computer Engineering at the University of Washington.

Quantum Sensing of Intermittent Signals

Realistic quantum sensors face a trade-off between the number of sensors measured in parallel and the control and readout fidelity (F) across the ensemble. For continuous signals, increasing the number of sensors by $1/F^2$ for $F < 1$ always recovers the sensitivity achieved when $F = 1$. However, when the signal is intermittent, more sensors are needed to recover the sensitivity achievable with one perfect quantum sensor. We demonstrate the importance of near-unity control fidelity and readout at the quantum projection noise limit by estimating the frequency components of a stochastic, intermittent signal with a single trapped ion sensor. Quantum sensing has historically focused on large ensembles of sensors operated far from the standard quantum limit, but these results show that this is insufficient for quantum sensing of intermittent signals and re-emphasizes the importance of the unique scaling of quantum projection noise near an eigenstate.

We strive to increase the sensitivity and utility of a trapped-ion sensor further through 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. ,

Moussa N’Gom

Dr. Moussa N’Gom is an Assistant Professor in the physics department at Rensselaer Polytechnic Institute (RPI). In addition to his teaching duties, professor N’Gom conduct fundamental research in quantum optics for quantum communication and the development of a photonics-based quantum computer. He received a NURI grant from NGA to conduct research on laser filament and its potential ability to ‘drill’ through cloud for clear channel free space optical communication. Professor N’Gom holds a BS in Electrical Engineering and Physics from the University of Wisconsin in Milwaukee and a Ph.D. in Physics from the University of Michigan in Ann Arbor.

Free Space Optical Communication Through Dynamic Media

Free Space Optical (FSO) Communication refers to wireless or unguided propagation of optical signals. FSO systems are used for high rate communication between fixed points over distances up to several kilometers. Despite the major advantages of FSO technology, its widespread use has been hampered by its rather disappointing link reliability particularly in long ranges due to atmospheric turbulence induced fading and sensitivity to weather conditions. The water ‘particles’ that form clouds or fog cause significant loss of received optical power. Even under ideal clear sky conditions, the absolute reliability of a laser communication link through the atmosphere is still physically limited by absorption of atmospheric constituents and the constantly present atmospheric turbulence. Ultrafast lasers provides an opportunity to reconsider laser transmission through dense clouds or fog with a fundamentally different approach: nonlinear propagation in the atmosphere and laser filamentation. A laser filament produces a shock wave that radially expels water droplets out of the beam path and its immediate surrounding. This creates a partially cleared channel significantly larger than the filament diameter, within clouds or fogs to allow unobstructed optical transmission through the atmosphere. The PI proposes to design and develop a hybrid laser system that simultaneously clears a path and transmits optical signals for an unobstructed FSO communication link. The hybrid laser system is composed of a femtosecond laser beam embedded in a donut shaped optical signal. The femtosecond laser pulses create the local cloudless transmission channel for the telecom beam to carry information unobstructed. The information carrying beam will be shaped and modulated using wavefront shaping methods that the PI has developed. This method when implemented, will have a great impact and lead to clear path optical transmission. The proposed study will also develop a method for the characterization of atmospheric turbulence as it impacts optical transmission paths. Further, the results from the study proposed can also be used as a catalyst to research full spectrum detection and characterization of plasma in space.



Keng Tiong (Kelvin) Ng

Dr. Keng Tiong (Kelvin) Ng completed his BSc in Chemical and Pharmaceutical Sciences in 2010, MSc in Drug Discovery and Development in 2011, and PhD in Pharmaceutical Chemistry in 2016, at the University of Sunderland (UK). During his BSc and MSc years, he undertook an industrial placement at Onyx Scientific (UK) and AstraZeneca (UK), specialising in analytical chemistry projects. Upon completion of his PhD, he then started his postdoctoral career at the University of Sunderland and two years later at King's College London. His research encompassed a range of disciplines, including peptide synthesis, analytical chemistry, and ecotoxicology. In 2019, he was awarded with a two-year UK Intelligence Community (IC) Postdoctoral Research Fellowship by the Royal Academy of Engineering, on a research project aimed at the identification of explosive threat precursor markers to intercept clandestine activity *via* wastewater analysis. He later moved to Imperial College London in 2020 to continue his UK IC fellowship programme, in collaboration with the Centre for the Protection of National Infrastructure (CPNI), Metropolitan Police Service and National Physical Laboratory (NPL). Aside from the postdoctoral role, he is also a member of Royal Society of Chemistry and a member of Health Protection Research Unit (HPRU) in Chemical and Radiation Threats and Hazards at Imperial College London. His research interests are wastewater analysis, illegal chemicals, explosives, and pharmaceutical analysis.

Identification of Illegal Manufacturing Activity via Wastewater Markers

A variety of legal and legitimate industrial, agricultural, pharmaceutical, veterinary chemicals and household products can be transformed for illegal purposes, such as explosive threats manufacturing, including homemade explosives (HMEs) and improvised explosive devices (IEDs). This has become an ongoing and a major concern to the governments and societies around the world; therefore, early identification of the illicit manufacture of explosive threat agents is critical for protection of public safety. Though there are many existing mechanisms available for explosive detection, an alternative approach for monitoring explosive activity through the detection of the synthesised final HMEs, as well as their precursors, stable transformation products and/or potential markers in wastewater is proposed. This is expected to be a vital contribution to existing knowledge as several HME 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. Occurrence of illegal drugs, alcohol, medications and other toxicants in the wastewater network of a city is well-established and documented to understand community consumption patterns, lifestyle and health status. To date, however, this process has not yet been widely applied to security threat agents. Therefore, the aim of this research project is to develop new capabilities for identifying and monitoring a large number of threats, particularly HMEs as well as their markers, to indicate clandestine synthesis activity *via* wastewater analysis. To identify potential HME markers, components including transformation products, impurities and additives present in the HMEs and household commercial products (known to be used for HME manufacturing) will be shortlisted through analytical measurement. Followed by occurrence screening in municipal wastewater to determine these shortlisted markers can reliably be used to indicate synthetic activity of illegal threats. Identity of some of these markers are not known but will be predicted later using an *in-silico* retention prediction tool. Ideally, candidate markers 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 sugar nitrates will be the initial focus of the research now, which will later be expanded to include other HMEs and nerve agents. The outcome of this research will be to preliminarily set reliable baseline thresholds for explosive threat markers in London wastewater and subsequently, extend these capabilities towards the localisation of threat production activity.



Laurel Orr

Dr. Orr is currently an Intelligence Community Postdoctoral Fellow at Stanford working with Christopher Re as part of the Hazy Research lab. In August of 2019, Dr. Orr graduated with a PhD from Paul G Allen School for Computer Science and Engineering at the University of Washington in Seattle. Dr. Orr was part of the Database Group and advised by Dan Suciu and Magdalena Balazinska. Dr. Orr's research interests are centered around the data management challenges associated with building, monitoring, and maintaining self-supervised embedding ecosystems.

Bootleg: Chasing the Tail of Named Entity Disambiguation

Named Entity Disambiguation (NED) is the task of mapping textual mentions to entities in a database. A key challenge in NED is generalizing to rarely seen entities, termed tail entities. Traditional NED systems use hand-tuned features to improve tail generalization, but these features make the system challenging to deploy and maintain. In 2018, a subset of the authors built and deployed a self-supervised NED system at a major technology company, which improved performance over its hand-tuned predecessor. Motivated to understand the core reasons for this improvement, we introduce Bootleg, a clean-slate, open-source, self-supervised NED system. In this talk, we'll show how to succeed on the tail by reasoning over structured data. We demonstrate that Bootleg matches or exceeds state-of-the-art performance on three NED benchmarks and that the learned representations from Bootleg demonstrate up to 8% performance lift in a production task. Finally, we observe that embeddings from self-supervised models like Bootleg are increasingly being served to downstream applications, creating an embedding ecosystem. We initiate the study of the data management challenges associated with this ecosystem.



Steven Owens

Capt Steven Owens is an Air Force physicist currently working on his Ph.D. at the Air Force Institute of Technology (AFIT). He graduated with a B.S. in physics from the U.S. Air Force Academy and M.S. in engineering physics from AFIT. He went on to work at Eglin AFB, FL, where he focused on weapon seeker technology for three years before returning to AFIT.

Pulsed Digital Holography System Efficiency Characterization

Digital holography (DH) in the off-axis image plane recording geometry with an amplitude-split 1064 nm laser pulse was used to measure the efficiencies of a pulsed source DH system. For zero path length difference between the signal and reference pulses, measurements of the signal efficiency (84.4%), reference efficiency (48%), and mixing efficiency (26%) resulted in an expected maximum total system efficiency of $10.5\% \pm 5.2\%$ and a measured maximum total system efficiency of $10.7\% \pm 6.9\%$. These efficiencies were then measured as a function of signal and reference pulse overlap via the time delay between pulse centers, then compared against theoretical values.



Chris Oxendine

Colonel Chris Oxendine, Ph.D. is the Director for the Center of Environmental and Geographic Sciences and an Associate Professor of Geospatial Information Sciences in the Department of Geography and Environmental Engineering at the United States Military Academy. He earned a Ph.D. in Earth Systems and GeoInformation Science from George Mason University (2013), a MS in Cartography/GIS from the University of Wisconsin-Madison (2004), and a BS in Mapping, Charting, & Geodesy from West Point (1996). His research interests include producing 3D models, visualizations & simulations from UAS

derived imagery, GIS analysis in social media, humanitarian assistance, and disaster response. For fun, Chris runs ultra-marathons and rows.

Sensitivity Analysis of Varying Spatial Resolution on the Determination of Helicopter Landing Zones

This presentation explores the variation and accuracy of Helicopter Landing Zone (HLZ) footprints as determined by different spatial resolutions in the required data used in the calculations. This presentation will discuss (1) the automated methodology used for the calculation of multiple HLZs at varying spatial resolutions at three different geographic areas of the world, (2) the methods and results of ground truth in each HLZ, and (3) the initial findings and results. The study sites for the research include the military training areas at West Point, NY., Fort Carson, CO., Pinon Canyon, CO., and Fort Richardson, AK.



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 single photon sources in II-VI

semiconductors and microwave-to-optical quantum state transduction with semiconductor quantum dots.

Single Photon Emission from Donor Bound Excitons in ZnSe

The generation of single photons is a fundamental task for many quantum communication and quantum information processing tasks. In order to develop a scalable platform based around these technologies, it is also desirable to integrate these sources with platforms that are compatible with modern fabrication techniques. In this presentation, I will highlight our work to develop a single photon source based on donor bound excitons in a Chlorine doped ZnSe quantum well. Furthermore, Chlorine atoms in the ZnSe lattice behave as electron donors and a single Chlorine bound exciton may also therefore serve as a potential matter qubit via its electron spin degree of freedom.



Pencho Petrushev

Dr. 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 six 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.

Discrete Poisson Extension Algorithm for Downward Continuation of the Gravity Anomaly

The main objective of this project is to find a practical solution of the problem for downward continuation of the gravity anomaly from the Earth topography to a reference sphere or ellipsoid in the presence of very high resolution data. More precisely, our main goal is to develop an algorithm and software for downward continuation of the gravity anomaly based on 2 arcminute resolution data with provable convergence to an accuracy that guaranties 10^{-6} relative error. We advance in two directions. First, we develop an algorithm for downward continuation in the 3-D case with 2' resolution data that is practically feasible. Our algorithm is a combination of a partition of unity on the reference sphere or ellipsoid and application of the Poisson operator. We arrive at this method by analyzing the algorithm for downward continuation of the gravity anomaly used in the development of the NGA gravimetric model EGM2008. After all it comes down to solving a large linear system, which as will be shown is practically feasible. Second, we present a complete solution of this problem in the 2-D case with 2' data mesh and heights defined by the Earth surface elevation profiles. Our next step is to complete the development of our algorithm and software for downward continuation in the 3-D case with 2' data and present them to NGA for implementation.



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, IARPA, DOD, DHS and the European Commission.

Generation and Management of Crowdsourced Place Gazetteers – Human Mobility

The study of human 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. This talk will not only address the data angle by surveying existing datasets and assessing their similarities and differences when it comes to studying human mobility, but we will also introduce simulation as a means to address gaps in our data and to assess future mobility scenarios. Although not representative of the entire population, social media data captures the sentiment of a significant portion of the population. Our research objective is to extract meaningful movement information from geo-located tweets and understand human mobility patterns in urban areas. To assess the suitability of social media data for comprehending mobility patterns, we compare the results to LODES data (Longitudinal Employer-Household Dynamics OD Employment Statistics) collected as part of the CENSUS LEHD program, Safe-graph mobility data, and Census Transportation Planning Program (CTPP) data. Although these datasets allow us to assess human mobility in terms of geography, what has been sorely missing is a comprehensive data set that also provides social networks and causal links as to why movement happens in the first place. To overcome these issues, we have infused a novel geographically explicit agent-based simulation framework to simulate human behavior and to create synthetic human patterns-of-life (i.e., a geo-social simulation). Such data not only captures the location of users over time, but also their motivation, and interactions via temporal social networks. The talk concludes with an outlook as to how data-infused simulation could result in a library of places that provides us with a dynamic view of the built environment and its population.



Michelle L. Povinelli

Dr. Michelle L. Povinelli is a Professor of Electrical Engineering and Physics and Gabilan Distinguished Professor of Science and Engineering 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. She is a Fellow of the OSA and SPIE and has >90 peer-reviewed journal publications.

Microstructured Materials with Engineered Thermal Emissivity

We are designing microstructured materials with customized and time-dependent thermal emissivity for applications in temperature regulation, signaling, and sensing. In a first project, we have designed “self-adaptive” materials that change their broadband thermal emissivity to maintain a fixed temperature. Our experimental results demonstrate the first direct evidence for dynamic thermal regulation, using a solid-state phase change material, vanadium dioxide. In a second project, we are investigating strategies for electrical tuning of emissivity. We have numerically demonstrated the use of electrical modulation to achieve violation of Kirchoff’s Law, the constraint that material absorptivity and emissivity be equal. The ability to remove this constraint suggests new possibilities for energy harvesting and remote sensing. Currently funded work by NGA is seeking to realize electrical modulation in experiment, using a novel strategy for InAs growth directly on metal substrates. We review our progress in fabricating and characterizing modulated-emissivity devices.



Andrew Sabelhaus

Dr. Andrew P. Sabelhaus is an Intelligence Community Postdoctoral Research Fellow in the department of Mechanical Engineering at Carnegie Mellon University. He received his Ph.D. in Mechanical Engineering at the University of California, Berkeley in 2019, in collaboration with NASA Ames Research Center's Intelligent Robotics Group. He received an M.S. from Berkeley in 2015, and a B.S. from the University of Maryland in 2012, both also in Mechanical Engineering. At Berkeley, he was a NASA Space Technology Research Fellow from 2015-2019 and an NSF Graduate Research Fellow from 2012-2015. Andrew's

research takes a control-oriented approach to the locomotion of soft and flexible robots, spanning problems in modeling, feedback, and design, with a vision toward autonomy and deployment of soft robots for field applications. He will be starting as an Assistant Professor in Mechanical Engineering at Boston University in January 2022.

Soft Robot Locomotion: Not as Hard as You Might Think

Our world faces hard problems that robots could help us solve, such as exploration where humans cannot venture, or transportation over impassible terrain. However, these environments are still challenging for state-of-the-art robots built with rigid mechanisms, which require precise models and high-frequency feedback control. In this talk, I will propose that these challenges can be overcome by building walking robots with soft and flexible materials. More importantly, taking a rigorous control-oriented approach to the modeling, feedback systems, and design of soft and flexible robots may not be as intimidating as it seems.

This talk will first demonstrate that in certain cases, approximations and simplistic assumptions in control can take advantage of the robustness inherent to soft materials. In those cases, tasks can be executed successfully without high-frequency feedback. Then, when certain canonical problems in control do arise in soft systems, such as instabilities and safety constraints, they can be addressed using well-known control techniques. In both situations, control of soft robots can indeed be comparable to or even simpler than with rigid systems. Finally, in the case when control problems for soft systems are truly unprecedented, machine learning methods may provide the needed models for predictions and feedback.

I will demonstrate two particular applications of these principles, one using a flexible tension network ("tensegrity") spine for a four-legged walking robot, and another using fully-soft robots that deform and walk using shape memory alloy wire actuators. Finally, I will outline a larger vision for soft robotics in-the-field and scaling up soft autonomous systems as part of my new research group at Boston University.



Hady R. Salloum

Dr. Hady Salloum is the Director of the DHS Science and Technology's National Center of Excellence for Maritime Security and the Sensor Technology and Applied Research (STAR) Center at Stevens Institute of Technology. He is also Professor of Electrical and Computer Engineering. He has over 35 years of experience in industry and academia, directing large-scale, complex research and development projects as well as field experiments and is currently responsible for leading research that spans various engineering and science disciplines.

He holds a Bachelors and Masters of Science degrees and a PhD in Electrical Engineering.

Perspectives of Aural Mapping Using Small Unmanned Aircraft Systems (UAS)

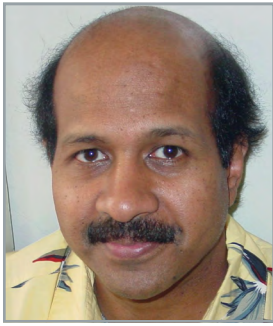
In its current state, geospatial intelligence (GEOINT) is based mainly on the exploitation and analysis of imagery and geospatial information. This may be complemented by the collection of acoustic information that provides additional features for the detection and classification of geographically referenced activities on Earth. The idea of exploiting a UAS for aural mapping seems obvious, but has not been realized yet due to the strong noise produced by a UAS.

The Sensor Technology and Applied Research (STAR) center at Stevens Institute of Technology has started to investigate opportunities connected with the installation of directional microphone systems on small UASs for aural mapping. Stevens research in the development of acoustic methods for the detection of low flying aircraft and UAS, supported by numerous lab and field experiments with various types of UASs provided a solid background for the application of a complex system approach to this problem.

Initial tests with several microphone arrays installed on a small UAS were conducted. For signal processing, we applied the generalized cross-correlation method that allows estimating the Time Difference of Arrival of wideband signals onto a pair of microphones, giving the UAS the capability of finding the direction to ground sources. Detailed investigation of UAS acoustic signatures and preliminary tests of the microphone system for a UAS demonstrated that fixed-wing UASs are much more suitable for aerial aural mapping than multirotor UASs. Fixed-wing UASs are quieter with sound that has much more stable harmonics that allow more effective UAS noise suppression. Other advantages of fixed-wing UASs include a much simpler structure in comparison with a rotary wing, ability to carry greater payloads for longer distances on less power, and a natural gliding capability without power that provides the opportunity for very accurate aural mapping with low acoustic noise.

Stevens was selected for award for a new project "Aural Mapping using Small Unmanned Aircraft Systems (UASs)." The goal of the suggested work is to investigate opportunities connected with the installation of directional microphone systems on small UASs for aural mapping. Passive acoustic arrays installed on UASs can detect various ground targets and may be augmented by cameras with the ability to automatically slew-to-cue to the detected targets. In this one-year project, several different microphone arrays will be installed on UASs and will be investigated in detail in both laboratory and field tests. The work will include three main components:

1. Development of several UAS microphone arrays and their installation on fixed-wing and multirotor UASs.
2. Development of signal processing methods providing highly directional reception of acoustic signals and UAS noise suppression.
3. Extensive laboratory and field testing of the developed systems and comparison of their performance.



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 near future.



Aswin Sankaranarayanan

Dr. Aswin Sankaranarayanan is an associate professor in the ECE department at CMU. His research interests are broadly in computational imaging, signal processing and computer vision. Aswin did his doctoral research at the University of Maryland where his dissertation won the distinguished dissertation award from the ECE department in 2009. He is the recipient of best paper awards in CVPR 2019 and ICCP 2021, a CIT Dean's Early Career Fellowship, and the NSF CAREER award.

Programmable Spectral Filter Arrays for Hyperspectral Imaging

Modulating the spectral dimension of light has numerous applications in imaging. While there are many techniques for achieving this, there are few, if any, for implementing a spatially-varying as well as programmable spectral filter. This work provides an optical design for implementing such a capability. Our key insight is that such capability can be implemented using liquid crystal spatial light modulator (SLM) since it provides a programmable array of liquid crystal cells, each of which can be purposed to act as a programmable spectral filter array. Relying on this insight, we provide an optical schematic and an associated lab prototype for realizing the capability, as well as address the associated challenges at implementation. We show a number of unique operating points with our prototype including single- and multi-image hyperspectral imaging, as well as its application in material identification and scene understanding.



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.

Blind and Federated Subgroup Robustness

Joint work with N. Martinez, M. Bertan, A. Papadaki, and M. Rodrigues.

With the wide adoption of machine learning algorithms across various application domains, there is a growing interest in the fairness properties of such algorithms. The vast majority of the activity in the field of group fairness addresses disparities between predefined groups based on protected features such as gender, age, and race, which need to be available at train, and often also at test, time. These approaches are static and retrospective, since algorithms designed to protect groups identified a priori cannot anticipate and protect the needs of different at-risk groups in the future. In this work we analyze the space of solutions for worst-case fairness beyond demographics, and propose Blind Pareto Fairness (BPF), a method that leverages no-regret dynamics to recover a fair minimax classifier that reduces worst-case risk of any potential subgroup of sufficient size and guarantees that the remaining population receives the best possible level of service. BPF addresses fairness beyond demographics, that is, it does not rely on predefined notions of at-risk groups, neither at train nor at test time. Our experimental results show that the proposed framework improves worst-case risk in multiple standard datasets, while simultaneously providing better levels of service for the remaining population, in comparison to competing methods. We will also discuss extensions and connections of this work to federated learning.



Mubarak Shah

Dr. Mubarak Shah, the UCF Trustee Chair Professor, is the founding director of Center for Research in Computer Visions. Dr. Shah is a fellow of IEEE, NAI, IAPR, AAAS and SPIE; and a member of Academy of Science, Engineering and Medicine of Florida (ASEMFL). He has published extensively on topics related to visual surveillance, tracking, human activity and action recognition, object detection and categorization, geo registration, visual crowd analysis, etc. He is a recipient of ACM SIGMM Technical Achievement award; ACM SIGMM Test of Time Honorable Mention Award; International Conference on Pattern Recognition

(ICPR) 2020 Best Scientific Paper Award.

Video Geo-Localization Employing Geo-Temporal Feature Learning

In this talk I will present a deep learning method to simultaneously learn the discriminative features between the query video frames and gallery images for estimating the geo-spatial trajectory of a query video. Based on a transformer encoder architecture, our GTFL model encodes the query and the gallery data separately, via two dedicated branches. The proposed GPS Loss and Clip Triplet Loss exploit the geographical and temporal proximity between the frames and the clips to jointly learn the query and gallery features. We also propose a deep learning approach to trajectory smoothing by predicting the outliers in the estimated GPS positions and learning the offsets to smooth the trajectory. We build a large dataset from four different regions of the USA; New York, San Francisco, Berkeley and Bay Area, using BDD driving videos as a query, and by collecting corresponding Google StreetView (GSV) Images for the gallery. We conducted extensive evaluations of the proposed method on this new dataset and validated that the proposed method works well on all four test regions.



Cyrus Shahabi

Dr. Cyrus Shahabi is a Professor of Computer Science, Electrical & Computer Engineering and Spatial Sciences; Helen N. and Emmett H. Jones Professor of Engineering; the chair of the Computer Science Department; and the director of the Integrated Media Systems Center (IMSC) at USC's Viterbi School of Engineering. He was co-founder of two USC spin-offs, Geosemble Technologies and Tallygo, which both were acquired in July 2012 and March 2019, respectively. He received his B.S. in Computer Engineering from Sharif University of Technology and his M.S. and Ph.D. Degrees in Computer Science from the

University of Southern California. He authored two books and more than three hundred research papers in databases, GIS and multimedia with more than 14 US Patents. He chaired the founding nomination committee of ACM SIGSPATIAL for its first term (2011-2014 term) and was the chair of ACM SIGSPATIAL for the 2017-2020 term. He was an invited speaker in the 2010 National Research Council (of the National Academies) Committee on New Research Directions for the National Geospatial-Intelligence Agency. He is currently on the editorial board of the ACM Transactions on Spatial Algorithms and Systems (TSAS). Dr. Shahabi is a fellow of IEEE, and a recipient of the ACM Distinguished Scientist award, U.S. Presidential Early Career Awards for Scientists and Engineers (PECASE), and the NSF CAREER award.

Deep Trajectory Clustering for Mobility-Behavior Analysis

Identifying mobility behaviors from rich trajectory data is of great economic and social interest to various applications including urban planning, marketing, public health and intelligence. One approach is to label each and every trajectory with a mobility behavior to utilize a supervised learning approach. However, the expense of labeling massive trajectory data is a barrier to supervised learning models. Alternatively, unsupervised approaches, such as clustering, can be used to cluster trajectories into similar groups based on their mobility behaviors. However, existing work on trajectory clustering often relies on similarity measurements that utilize raw spatial and/or temporal information of trajectories. These measures are incapable of identifying similar moving behaviors that exhibit varying spatiotemporal scales of movement. To address these challenges, we propose an unsupervised neural approach for mobility behavior clustering, called the Deep Embedded Trajectory Clustering network (DETECT). DETECT operates in three parts: first, it transforms the trajectories by summarizing their critical parts and augmenting them with context derived from their geographical locality (e.g., using POIs from gazetteers). Next, it learns a powerful representation of trajectories in the latent space of behaviors, thus enabling a clustering function (such as K-means) to be applied. Finally, a clustering-oriented loss is directly built on the embedded features to jointly perform feature refinement and cluster assignment, thus improving separability between mobility behaviors. Exhaustive quantitative and qualitative experiments on two real-world datasets demonstrate the effectiveness of our approach for mobility behavior analyses. Future research includes handling the case where geographical context is not available.



Joseph Shaheen

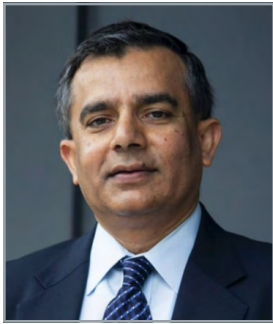
Dr. Joseph Shaheen is an Intelligence Community Postdoc Fellow (ODNI/NCTC) at Georgetown University's Massive Data Institute at the McCourt School of Public Policy. Dr. Shaheen earned his doctorate in Computational Social Science from George Mason University with a dissertation on economic policy and population-scale data analysis of Internal Revenue Service records. There, he studied all U.S. firms from a biologically-grounded perspective.

Following his U.S. State Department-funded assignment with the NATO STRATCOM Centre of Excellence where he conducted large scale analysis and provided policy recommendations in the fight against ISIS/ISIL/Daesh, he has been a guest speaker on issues of Information and *Social Media Warfare*—a term closely associated with his 2015 NATO report—at the Pentagon (J-39 SMA), NATO Defense Against Terrorism COE, National Defense University, OMCC and others.

A life-long scholar, Dr. Shaheen has received training from academic leaders in Social Network Analysis and has been recognized as an honorary Links Center Fellow in 2015. He has appeared on CNN HLN, FOX NEWS, NBC News, Entrepreneur Magazine and has been invited to participate in the 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.

MRQAP as a Causal-Comparative Tool in Relational Agent-Based Models

Agent-based modeling is a powerful simulation tool used to understand and explain complex systems. Recently, the methodology has gained widespread support and interest from the so-called mainstream of network science and social network analysis communities after much dismissal and critique. Combined with a robust statistical modeling tool we show how agent-based modeling can be used to generate and then compare social experiments *in silico*. Our case study compares two network simulations. We use the Multiple Regression Quadratic Assignment Procedure (MRQAP) as a causal-comparative tool to determine how social effects diverge given a different set of rules from 2 separate models and find a reordering of parameter estimate magnitudes.



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. 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 US DOD- NGA (2015), Future Workforce for Geospatial Intelligence (2011) and Priorities for GEOINT Research (2004-2005). He has also collaborated with many NGA scientists (e.g., Beth Driver, Renee Laubscher, Dr. James Kang, Dr. Christopher Farah, Dr. Christopher Rouly, and Major Trung Vuong) across four NURI grants.

Identifying Aberration Patterns in Multi-attribute Trajectory Data with Gaps

We investigate novel 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 explore a three-phase approach. First, we studied 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 examine query methods to efficiently discover aberration patterns with known spatiotemporal signatures. Third, we probe 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) is used to evaluate the computational efficiency of the proposed methods. Furthermore, case studies are used to evaluate the effectiveness of proposed methods.



Kevin Singh

Dr. Kevin Singh is an IC Postdoctoral Fellow in the Bernien Lab at the Pritzker School of Molecular Engineering at the University of Chicago. He received his S.B. in Physics (2013) from the Massachusetts Institute of Technology and his Ph.D. in Physics (2019) from the University of California, Santa Barbara working with Prof. David Weld. His main research interests are in the development of new tools and strategies to control the behavior of strongly interacting many-body quantum systems for novel real-world applications and devices. During his Ph.D., he built an ultracold atom experiment that uses Bose-Einstein condensates of lithium atoms in strongly-driven optical lattices to study non-equilibrium quantum phenomena. As an IC Postdoc, he is building a dual-element programmable quantum simulator that currently operates with over several hundred individual rubidium and cesium atomic qubits prepared in two-dimensional optical tweezer arrays. An important component of his research involves using machine learning techniques, in particular Bayesian inference and reinforcement learning, to improve the quantum sensing capabilities of the quantum simulator and to optimize the preparation fidelity of large-scale highly entangled quantum states.

Engineering and Control of Large-Scale Rydberg Atom Based Quantum Simulators

Arrays of neutral atoms are powerful platforms for building large-scale programmable quantum machines and have important applications in quantum sensing, quantum information processing, and the development of quantum networks. In this talk, I will present the latest results in our development of a quantum simulator that interweaves two species of atomic qubit arrays (rubidium and cesium) to suppress qubit crosstalk and open up new research avenues for multi-qubit manipulation and error-correction. Strong interactions between the atomic qubits are engineered by coherently exciting the atoms to highly excited principle quantum number states called Rydberg states. In addition to generating interactions, these Rydberg states are ideal quantum sensors for the measurement of static electric fields, static magnetic fields, and of electromagnetic radiation spanning from the radiofrequency to terahertz spectrum. I will discuss how we can use a combination of machine learning techniques and the sensitivity of these Rydberg states to rapidly measure the electric and magnetic field environment to improve both the Rydberg atom as a quantum sensor and to optimize the performance and stability of our programmable quantum simulator.



Todd Small

Major Todd Small currently serves on active duty in the United States Air Force. Just this month, he earned his PhD in Applied Physics from the Air Force Institute of Technology (AFIT) in the field of optics. His research focused on improving both measurement and modeling of material bidirectional reflectance distribution functions (BRDFs), with emphasis on spacecraft materials relevant to remote sensing applications such as light curve analysis. Todd's next assignment will be as assistant professor and Deputy Department Head in AFIT's Department of Engineering Physics. He previously obtained his Bachelor's Degree in Astronautical Engineering from the United States Air Force Academy in 2008, and his Master's Degree in Aero/Astro Engineering from the Massachusetts Institute of Technology in 2010. Between his Master's Degree and PhD, he served as a U-28 pilot stationed at Hurlburt Field, Florida, within the Air Force Special Operations Command (AFSOC). During deployments to Africa and the Middle East, he gained extensive experience flying manned intelligence, surveillance, and reconnaissance (ISR) missions, and also served as the director of plans for a theater-wide special operations air component.

Solar Cell BRDF Measurement and Modeling with Out-of-Plane Data

The bi-directional reflectance distribution function (BRDF) describes the directional (or spatial) nature of light's reflectance from a material surface. To interpret or predict observations comprised of reflected light, remote sensing applications such as satellite light curve analysis typically rely on isotropic microfacet BRDF models to strike a balance between physical accuracy and computational efficiency. However, microfacet models inherently assume geometric optics, and most are only informed by material measurements within the plane of incidence (in-plane). As a result, they fundamentally cannot represent reflection outside the plane of incidence (out-of-plane) from materials with anisotropic surface characteristics, nor phenomena rooted in the wave nature of light such as diffraction. Meanwhile, applications such as light curve analysis still suffer from disagreement between observation and simulation.

This work is primarily motivated by the hypothesis that unmeasured and unmodeled out-of-plane reflection may account for at least some disagreement between light curve simulation and observation. First, a new system is designed and implemented which successfully measures both in-plane and out-of-plane material BRDFs near the specular peak with angular resolution better than 0.001° . Since solar cells are relatively significant contributors to satellite reflection signatures, the new system is then used to measure the BRDF of a commercially available satellite solar cell using a visible red laser source. The measurements detect two previously unmodeled reflectance features with out-of-plane components: 1) two specular peaks caused by different material surfaces with slightly different normal directions, and 2) a diffraction pattern caused by metal conducting bars periodically spaced in one direction across the solar cell surface.

After validation, the measurements are used to inform the creation of a new closed-form BRDF model capable of describing the out-of-plane behavior. In particular, the diffraction pattern is modeled using an adjusted solution for Fraunhofer diffraction through two rectangular stripes. Even when model parameters are manually chosen – based largely on physical material properties – the model successfully replicates the observed features both qualitatively and quantitatively.

The results provide evidence that diffraction from solar cells warrants further investigation within the context of light curve analysis. Next steps involve incorporating the updated solar cell BRDF model into radiometric simulations and testing its impact compared to previous models as well as observational data. Additionally, since observations are often collected across spectral bands, measurements at other wavelengths could be used to validate or further improve the model.



Ryan Smith

Dr. Ryan Smith is an Assistant Professor in the Geological Engineering program at Missouri University of Science and Technology, which he joined in Fall 2018. He earned his Ph.D. at Stanford University in Geophysics in 2018, and his B.S. in Geology at Brigham Young University, Utah in 2014. Dr. Smith is a remote sensing hydrologist. He studies groundwater resources and quality at global and local scales by combining satellite, airborne and ground-based geophysical, and in-situ datasets, using both process-based models and machine learning techniques. Dr. Smith's research is funded by NASA, NGA, USGS, and NSF.

Dr. Smith serves as an Associate Editor for *Hydrogeology Journal*, and as a Guest Editor for *Remote Sensing in Earth Systems Sciences*.

Global Monitoring of Groundwater Storage Change Using Automated Assessment of Land Subsidence

Water security impacts both food and drinking water availability, and is an issue of critical importance especially for nations with scarce water resources or water resources that cross political boundaries, yet can be difficult to characterize, particularly in data-scarce regions. Groundwater, which supplies roughly one third of global water demand, is particularly challenging to monitor without ground-based sampling networks, which typically do not exist or are not made publicly available in many of the nations where water security is most dire.

One concerning consequence of groundwater withdrawals is land subsidence, which causes significant infrastructure damage, reduces aquifer storage capacity, and provides a dramatic visible demonstration of groundwater usage and scarcity. Interferometric Synthetic Aperture Radar (InSAR) can be used to estimate land surface displacements with mm- to cm- scale accuracy, with a spatial resolution of 20 – 100 m, and has been used by many researchers to improve understanding of actively monitored groundwater systems, with a focus on local, data-rich regions. Very little research has been done to understand how InSAR data could be used in areas with little or no in-situ groundwater monitoring, or scaled to study groundwater systems over large (country or continental) regions.

Our goal here is to develop machine learning methods that predict pumping-induced subsidence by learning relationships between existing satellite and regional hydrologic datasets and land subsidence. We are currently using random forests to produce maps of subsidence due to groundwater extraction at the global scale at 2 km resolution, enabling the observation of the loss of groundwater storage at higher resolution than previously possible in regions with little or no ground-based hydrologic information. The algorithm is calibrated using a compilation of over 20 independent InSAR studies from different regions of the globe. We plan to use these maps to identify two regions with high water depletion, and process InSAR data over these regions. Comparing the observed subsidence from InSAR data with estimated subsidence from our machine learning algorithms will allow us to further characterize aquifer properties. Implementing this method requires no ground-truth data and can be used to make first-order estimates of groundwater storage change, and forecast future changes given land use change, in data-poor regions.



Martin Smyth

Dr. Martin Smyth is a research and development scientist in the Research Directorate at the National Geospatial-Intelligence Agency (NGA), and a visiting scholar at the Institute for Advanced Computational Science, Stony Brook University. As a visiting scientist at NGA, he worked with research mentor Dr. Michael Egan to advance the knowledge frontier of temporal dynamics in global social media data. Their transdisciplinary research applied 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. Dr. Smyth returns to ICARS this year to share findings of current work on the structure of social media user-networks.

Modeling Social Media Networks as Hyperbolic Random Graphs

Martin Smyth, Joseph Finn, Cody Buntain, Joshua Garland, Andrés Rodríguez Rey, and Alex Cloninger

This paper considers the structural characteristics of social media networks, and proposes a technique for generating graph-objects exhibiting these same characteristics. Groundbreaking research by Ugander et al. [2011] demonstrated that the undirected degree parameter for networks of Facebook users both globally and within the United States share a common distribution. As is the case for most real-world networks, the observed distribution deviates from the strict scale-free condition; plotted on log-log scaled axes, the distribution exhibits a pronounced concave deformation away from linearity [cf. Ugander et al. 2011]. Using the published degree-sequence for the network [Backstrom et al. 2012], we show that this distribution is best fit with a log-normal curve. We posit that the degree distribution for an ideal *simulacrum* social media network should exhibit similar characteristics.

Characterizing the structure of real-world networks has been a topic of significant interest in the research community, with network topology understood as an important influence on network phenomena. (The present paper proceeds from our own earlier exploration of information-processing on social media service platforms). Following their formal specification by Krioukov et al. [2009], hyperbolic random graphs (HRGs) have been demonstrated to capture structural features of real-world networks [Bläsius et al. 2019, Allard and Serrano 2019]. However, the degree distribution observed by Ugander et al. [2011] exhibits features that cannot be replicated with a simple HRG model.

Accordingly, we propose to model social media networks via a multi-scale HRG-generating algorithm.

We anticipate that leveraging this technique will yield model graph-objects that more closely resemble real-world social networks, allowing more sophisticated computational modeling of social network phenomena.

Acknowledgements

This research was supported in part by an appointment to the Visiting Scientist Research Participation Program at the National Geospatial-Intelligence Agency (NGA), United States Department of Defense. The Visiting Scientist Program is administered by Oak Ridge Institute for Science and Education (ORISE), an asset of the United States Department of Energy operated by Oak Ridge Associated Universities (ORAU).

Funded research was made possible with generous in-kind support provided by the Institute for Advanced Computational Science (IACS), Stony Brook University, State University of New York.

The authors gratefully acknowledge Dr. Michael Egan, National Aeronautics and Space Administration (NASA), for posing the original question leading to this research.



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 near future.



Julie Spencer

Dr. Julie Spencer is an IC Postdoctoral Fellow at Los Alamos National Laboratory, working with Dr. Anthony Nguy-Robertson, Dr. Erik J. Scully, and Dr. Carrie A. Manore. She earned a B.A. in mathematics and philosophy at St. John's College (1986), and M.S. (2017) and Ph.D. (2020) degrees in computational biology at the University of New Mexico. She was awarded an NSF ADVANCE Dissertation Excellence Fellowship in 2020 for her dissertation, *Chronic and acute respiratory pathogens: evolutionary and epidemiological characteristics of tuberculosis, influenza-like illness, and COVID-19*. As a member of the COVID-19 Modeling

& Analysis Team, she received the Los Alamos National Laboratory 2020 Distinguished Performance Award. Dr. Spencer is interested in leveraging data fusion and predictive analytics to transfer insights gained from forecasting endemic diseases to anticipating outbreaks of sporadic diseases.

Forecasting Dengue in Brazil at High Resolution

Dengue is a mosquito-borne viral disease that infects over 400 million people per year worldwide, resulting in vast disease burden. Dengue is transmitted primarily by mosquito species *Aedes aegypti* and *Aedes albopictus*, and is endemic in tropical regions. However, wherever the mosquitoes that transmit the disease expand their habitats, the disease can spread.

A forecasting system for mosquito-borne diseases such as dengue is needed for decision-makers to be able to allocate resources in a timely manner to mitigate disease burden. Predicting seasonal and sporadic outbreaks for mosquito-borne diseases is challenging because mosquito populations are inherently difficult to track. Recent studies have included environmental information such as weather and satellite data streams as proxies for mosquito density. A few of these studies have been encouragingly successful at predicting historic cases of dengue; however, these have been conducted at broad scales or at a single location, which obscures important underlying geographic heterogeneities. Here, we address a need for high-resolution dengue forecasting that incorporates environmental proxies for mosquito density, as well as human demographics and behavior.

We apply penalized regression models (Ridge, LASSO, and Elastic Net) to historic dengue data for five representative metro areas in Brazil at the municipality level of resolution. To reduce dimensionality and multicollinearity of predictor variables, we use a hierarchical clustering method. We train our models on six years of data, test our forecasts on one year, and quantify the accuracy of forecasts using mean squared error (MSE) and R^2 . We create maps to visualize incidence, environmental and demographic variables, and forecasting accuracy. We use R for all data analysis and visualization.

We find that varied combinations of environmental predictors work best in different municipalities, suggesting that an adaptive modeling approach is appropriate. Despite the added benefits of adaptive modeling, a surprising amount of geographic heterogeneity exists in historic dengue incidence and thus in the ability of our models to forecast it. The next step in this project is to assess whether incorporating time lags within environmental data streams and additional social media data improves our forecasts. These approaches can potentially help anticipate emerging outbreaks of dengue, as well as of sporadic diseases such as chikungunya and Zika.



Steven Spiegel

Steven Spiegel is a visiting scientist working in the Research Directorate at the National Geospatial-Intelligence Agency (NGA). His research focuses on point cloud collection, processing, and classification. These point cloud collections include EO and LiDAR data. Steven received a master's degree in geographic information sciences from Saint Louis University and an undergraduate degree in mathematics from Truman State University.

Using Gaming Environments for Training Deep Learning Algorithms on Point Clouds

Deep neural networks and convolutional neural networks have demonstrated a high level of accuracy in classifying and segmenting 2D. There exists large datasets that have been meticulously labeled and allow for training these neural networks. This can also be seen in use for 3D datasets, particularly for point clouds generated by electro-optical (EO) devices and LiDAR (Light Detection and Ranging) scanners. The accuracy for these neural networks surpass those of traditional machine learning algorithms and carry the same hierarchical learning benefits of image classification. The primary drawback is there are fewer labeled datasets available for use than that of imagery, particularly for the semantic segmentation tasks. This study evaluates the use of simulated 3D point clouds of urban environments for training a deep convoluted neural network. We used a simulated 16 channel LiDAR sensor in an environment called CARLA (Car Learning to Act) to collect labeled training data in an urban setting. We also attempted real world noise in the sensor to help improve accuracy. We then trained the Kernel Point Convolution Segmentation network and tested it on a real world LiDAR dataset. Our results demonstrated that high accuracies can be obtained using a simulated urban environment and sensor.



Cedric Spire

Dr. Cedric Spire is currently am UK Intelligence Community Postdoctoral Fellow (RAEng UK IC 2019) at Brunel University London, working on the development of automated anomaly detection and correction methods in structured databases. This research is done in collaboration with a UK public sector organisation. Dr. Spire has a background in Physics (BSc) and Statistics (MSc) and have developed a strong interest in using machine learning to tackle real-world challenges and benefit society in any way possible.

Automated Error Detection and Correction 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 might result in new errors being introduced. 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 a prototype of such a GUI that can perform search, edit and cleaning operations as well as visualisation tasks on tabulated databases.



Bowen Tan

Bowen Tan is Ph.D. student in Language Technologies Institute at Carnegie Mellon University. He received his Bachelor's degree in Computer Science from Shanghai Jiao Tong University in 2019. His research interests lie in the broad area of machine learning, natural language processing, ML systems and other application domains.

Toward Knowledge and Structure-rich Text Generation

My research lies in Machine Learning (ML) and Natural Language Processing (NLP) in general, including text generation, knowledge graph, dialogue systems, reinforcement learning, graph neural networks, and composable ML systems. Specially, I am interested in the systemization of machine learning paradigms, to enable training AI agents with arbitrary combinations of experiences (e.g., data examples, structured knowledge, adversaries, auxiliary models).



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.

Metapopulation Dynamics of Outbreaks and their Management

Y. Tao^{1,2}, K. Lafferty^{2,3,4}, A. Hasting⁵, I. Hanski, O. Ovaskainen⁶

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³Marine Science Institute, University of California, Santa Barbara

⁴US Geological Survey

⁵Department of Environmental Science and Policy, University of California, Davis

⁶Organismal and Evolutionary Biology Research Programme, University of Helsinki

The classical concept of metapopulation describes a network of spatially separated populations connected through dispersal and competition. It is principally concerned with how the frequencies of local extinctions and recolonizations influence the long-term persistence of a species on a large spatial scale. In recent years, metapopulation dynamics have become of great interest to disease research despite generally having a goal opposite of that in conservation ecology, i.e., driving the pathogen to extinction. Metapopulation models thus continue to offer important insights, particularly into the effectiveness of competing strategies for outbreak control.

To facilitate analytical tractability, metapopulation theory has historically made simplifying assumptions about the spatial structures of a landscape and the scales of interactions between various ecological processes therein, from individual behaviors to environmental conditions. In the context of epidemiology, this conventional approach of masking spatial details can greatly limit the predictive power of a model to assess how concurrent changes in host movement, spatial distribution of transmission risk, and regions of vaccine coverage can jointly impact outbreak trajectories. Here, we developed a unified, spatially explicit framework using individual-based modeling to more realistically capture the disease dynamics under a set of possible outbreak scenarios.

Our model connects three quantities commonly used to describe metapopulation dynamics: large-scale disease prevalence, time to regional pathogen eradication, and spatial synchronization of recurrent outbreaks. The results are concordant with classical metapopulation theory while also revealing parametric conditions where the dynamics deviate sharply from the null expectations. Furthermore, our study tests the practicality of several standard methodologies, identifying drawbacks of using mean-field approximations, overlooking the geography of vaccine coverage, and extracting local patterns from incidence data collected over extensive areas.



Marko Tesic

Dr. Marko Tesic is a Royal Academy of Engineering UK IC postdoctoral research fellow at Birkbeck, University of London. He currently focuses on explainable AI (XAI). Many current AI systems are built to produce explanations of their decisions. Marko approaches the problems in XAI from a psychological (human) perspective and aims to identify the types of these explanations that would be appropriate for a human user.

He is also exploring the relationship between explanation and trust in AI systems: Do all explanations increase trust? Is it sometimes better not to provide an explanation? What are the roles of explanations in rebuilding trust in outputs of an AI system?

Marko's background is in psychology (PhD), logic and philosophy of science (MA) and philosophy (BA). In his PhD, apart from exploring the roles of explanations, he's also investigated human causal-probabilistic reasoning. A large part of his research is around causal Bayesian network (CBNs), an AI technique. CBNs are graphical models that can encode both causal and probabilistic information. He has applied CBNs in different areas, including finance, psychology, and philosophy.

Marko was a part of an IARPA funded project called 'Bayesian Argumentation via Delphi' (BARD), where he was involved in (i) creating intelligence gathering-inspired situations (ii) building Bayesian network models of these situations, and (iii) testing people's evidential, causal, and probabilistic reasoning with and without the help of a Bayesian network modelling tool. He was also a Research Intern at BlackRock, the world's largest asset manager, where he explored (causal) relationships between investment factors and environmental, social, and governance (ESG) criteria using (causal) Bayesian networks.

The Impact of Explanations as Communicative Acts on Belief in a Claim: The Role of Source Reliability

Providing an explanation is a communicative act. It includes an explainee, a person who is receiving an explanation and an explainer, a person who provides an explanation and attempts to influence explainee's beliefs. The majority of research on explanation has focused on how explanations alter an explainee's beliefs. However, one general feature of communicative acts is that they also provide information about the speaker, such as the speaker's reliability.

To explore the role of reliability in the context of explanations, we conducted three experiments. All three experiments utilized dialogues between two people on five different issues and included everyday explanations. We found that (i) in line with the previous literature, providing an explanation for a claim increased people's confidence in the claim; (ii) providing an explanation increased people's perceived reliability of the explainer; (iii) the reliability of the explainer mostly mediated the effect of providing an explanation; (iv) providing an explanation had a significantly greater impact on people's confidence when explainer's reliability was low compared to when that reliability was high, and (v) an expert who did not provide an explanation for their claim had the same impact on people's confidence as a non-expert who provided a good explanation for their claims.



Ammon Thompson

Dr. Ammon Thompson earned his PhD in Evolutionary Biology at the University of Texas at Austin where he studied the molecular evolution of gene families. Dr. Thompson then worked as a Postdoctoral Fellow at the University of California, Davis where he developed statistical methods for analyzing organ transcriptome evolution. In February 2021, Dr. Thompson began working as a Visiting Scientist for NGA.

Learning about the Geospatial Spread of Pathogens from their Genomes

Genome sequencing has become essential to understanding infectious disease outbreaks. Genomic, geographic, and disease prevalence data are analyzed with phylogeographic models to shed light on the history and mechanism of disease transmission between people, locations and demographic groups. Insights from phylogeographic analysis help provide guidance on ways to mitigate or prevent future disease outbreaks locally and globally. In recent months there has been significant progress in the development of complex phylogeographic models to harness the rapidly increasing amount of genomic data.

It is a significant challenge to decide which model is most appropriate and which data are most informative to answer various epidemiological questions. And, despite the high degree of complexity of phylogeographic models, there are still many simplifying assumptions that are necessary for computational efficiency. Computational methods such as Monte Carlo simulations can often take days and involve several iterations of tuning and troubleshooting. This sometimes necessitates coarse approximations in the models such as ignoring uncertainty in genealogical estimates of pathogen relationships, migration rates among locations, and how these processes interact.

Recent research has shown that neural networks trained with simulated phylogenetic data can yield inferences with comparable accuracy to sophisticated phylogenetic methods and do so in seconds. Neural networks trained with real-world data augmented with simulated data may speed up computation and fill in the gaps where phylogeographic models are overly simplistic. Adding such neural networks to a phylogeographic analysis pipeline may also facilitate the incorporation of more data types.

To begin to explore the potential of machine learning in phylogeography, my collaborators and I are developing a computational pipeline that simulates genome sequences under diverse epidemic scenarios including uneven sampling in space and time, superspreading events and individuals, and scenarios with public health interventions such as travel restrictions and lock-downs. Our simulation pipeline simulates epidemics where the viral genealogy, genome sequence, counts, and transmission histories are known in space and time. These simulated data will be used to train a neural network. Using real and simulated test data, I will explore the accuracy and computational cost of analyses that use trained neural networks relative to current phylogeographic methods. This research will reveal the potential and limitations of machine learning in phylogeographic analysis.



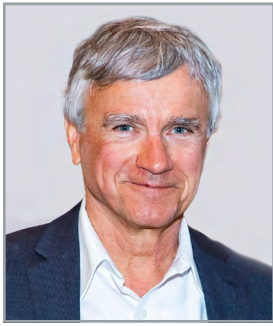
Susanna Todaro

Dr. Susanna Todaro is an IC Postdoctoral Fellow at the Massachusetts Institute of Technology. She received her Ph.D. in Physics in 2020 from the University of Colorado in Boulder, where she studied techniques for scaling up trapped-ion quantum computing systems in the Ion Storage Group at the National Institute of Standards and Technology. She currently continues to study trapped ion quantum computing in the lab of Isaac Chuang at MIT, closely collaborating with researchers at MIT-Lincoln Laboratory. Her current research focuses on novel qubit encodings in trapped ion systems.

Trapped-Ion Quantum Information with Metastable Qubits

Trapped-ion quantum information experiments have generally encoded the qubit either between sublevels of the ground electronic state or between the ground state and a long-lived metastable state. These qubit encodings have enabled exciting results, including high-fidelity two-qubit gates and the implementation of rudimentary quantum algorithms on trapped-ion quantum computers. However, many proposals for scaling to larger trapped-ion systems rely on the use of a second ion species as a sympathetic coolant or an ancilla, which introduces substantial increased experimental complexity.

I will present work investigating another category of qubits: the metastable qubit, in which the qubit is encoded in sublevels of a long-lived metastable state. Qubits in this metastable manifold would be largely insensitive to scattered laser light addressing a neighboring qubit in the ground state manifold and vice versa. This could enable quasi-dual species operation, in which many of the applications of dual-species ion trapping, such as for sympathetic cooling or ancilla qubits in quantum error correcting codes, could be implemented in a chain of identical ions. This would improve the vibrational mode structure and potentially reduce experimental complexity. I will present experimental progress towards metastable qubit operations using sublevels of the $^2D_{5/2}$ state of Sr^+ and Ba^+ ions, which have accessible visible and infrared transition wavelengths and an appropriate atomic structure for encoding quantum information in a metastable qubit.



Charles K. 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 Environment

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 use ground vehicles for initial tests. 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.



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. 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

This 3D modeling effort aims to better understand how light detection and ranging (LiDAR) laser light propagates through tree canopies. LiDAR has seen widespread use to measure 3D vegetation structure, but it is not abundantly apparent how laser light propagates through a multi-layered forest canopy and, critically, which portions of the 3D space have been adequately sampled or remain unsampled. We used a physics-based, first-principles radiometric model simulation tool (DIRSIG) and a detailed virtual scene of a northeastern forest to i) accurately model reflectance, transmission and absorption (380-2500nm), ii) for multispectral, hyperspectral, and LiDAR sensing modalities. Here we highlight the methodology for creating and validating the virtual scene, which will be used for to examine the effects of various LiDAR parameters, e.g., wavelength, beam geometry, etc., on sub-canopy detection.

The virtual forest scene is a recreation of an actual research plot in Harvard Forest, a National Ecological Observatory Network (NEON) research site (Petersham, MA). Field data from the online Harvard Forest Data Archive and sensor data from the 2019 NEON hyperspectral (HSI) and LiDAR platforms were used to create a realistic 24ha forest, filled with over 100,000 objects, representing 35 unique tree, shrub, and grass species. The terrain map and individual tree heights were calculated using both a LiDAR canopy height model, and a diameter-at-breast-height (dbh)-based regression model. Optical properties (reflectance and transmittance) for each species were obtained from real measurements taken from the online ecological spectral database ECOSIS (ecosis.org). Spectral variation was created via PROSPECT (pypi.org/project/prosail), by randomly adjusting leaf parameters. Optical properties for species and soil types, i.e., grasses, shrubs, wetland soil and dirt roads, were derived from HSI imagery. 3D models of vegetation were designed using OnyxTREE (V. 7.0; www.onyxtree.com), and instantiated in the scene at known locations. Additional objects (vehicles/structures) were placed at locations varying in leaf area index (LAI).

RGB, HSI (380-2500nm), and LiDAR sensors were successfully simulated (Figures 1a-c), during which we observed that the variation in canopy color, tree species, and density are clearly visible, thus providing a realistic feel to the scene (Figure 1a). Visually the real image looks denser, due to natural tree overlap, although the simulation is geographically accurate. This discrepancy was attributed to our models not incorporating crown competition. Spectrally the simulation closely matches the 2019 measured values, with normalized difference vegetation index (NDVI) and LAI indices used to confirm similar means and standard deviations. Next steps include a more extensive vetting of the actual scene, with field data captured this summer, followed by algorithm development for waveform target detection, 3D voxel traversal, and sampling maps.



Lucy S. Vlietstra

Dr. Lucy Vlietstra is a professor of marine science at the U.S. Coast Guard Academy, New London, Connecticut. She teaches courses in Marine Ecology, Emergency Management, Research in Geospatial Science, and Atmospheric and Marine Science. Her background includes research on the ecological relationships between marine predators and their prey in the Bering Sea and the role of climate change in shaping the distribution of shipping traffic in U.S. Arctic waters and implications for maritime safety and environmental protection. Dr. Vlietstra coordinates the institution's partnership with the National Geospatial-Intelligence

Agency, which offers research and internship opportunities to Coast Guard Academy cadets interested in exploring problems at the interface of marine science and geospatial intelligence.

Arctic GEOINT in Undergraduate Marine Science Research: Are Commercial Fishing Vessels Following Fish Poleward?

Rising ocean temperature is considered the primary factor driving large-scale, poleward shifts in the distribution of many marine fish populations in the Northern Hemisphere. Among the species showing poleward shifts are some groundfish of high commercial value in the Bering Sea, such as walleye pollock and Pacific cod. This region supports the nation's largest commercial fishery in terms of volume, so spatial shifts in heavily targeted species could promote a dramatic redistribution of commercial fishing effort, with potential implications for Coast Guard operations. This presentation describes how a research project in geospatial intelligence is incorporated into an undergraduate program in marine and environmental science at the U.S. Coast Guard Academy. We tested the hypothesis that commercial fishing vessels have shifted their distribution northward between January 2014 and February 2021, in effect, following the fish. We investigated this idea by acquiring satellite-derived (Vessel Monitoring System) fishing vessel position reports from the National Oceanic and Atmospheric Administration and uploaded them into ArcGIS Pro. We applied a grid pattern across the eastern Bering Sea, and summed the number of reports in each 50 x 50 km cell. We imported the results into MATLAB and used a Mann-Kendall Trend Test to detect significant increasing or decreasing temporal trends in the number of position reports within each cell. Statistical results (P-values) were uploaded into ArcGIS Pro to visualize regions where vessel density consistently increased (i.e., emerging hotspots) or decreased (i.e., emerging cold spots) since January 2014. Overall, we found poleward shifts (emerging hot spots in high latitudes and emerging cold spots in low latitudes) in fishing vessels during months when the greatest number of fishing vessels were underway in the U.S. Bering Sea as a whole, July-August and January, as well as in December. Months with the fewest fishing vessels (except December) showed either no significant trend, significant trends but in no clear direction, or a southward shift over time (emerging hot spots in low latitudes and emerging cold spots in high latitudes). Our observations of poleward shifts in fishing vessel distribution during the busiest fishing seasons in the eastern Bering Sea may have implications for mariner safety, law enforcement, and fisheries management, since high-latitude fishing may occur in more hazardous seas, closer to Arctic waters where commercial fishing is prohibited, and in areas with limited access to emergency response assets. Future research will evaluate the validity of these predictions as well as the strength of correlations between groundfish and commercial fishing vessel density, as we have yet to determine whether the patterns observed are directly linked to large-scale shifts in commercially targeted fish or to other environmental or economic factors.



Regina E. 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 near future.



Michael Weylandt

Dr. Michael Weylandt is currently an Intelligence Community Postdoctoral Fellow, working with George Michailidis at the University of Florida. His work focuses on statistical machine learning theory for structured multivariate time series, viewed through a graphical model lens. His work has been recognized with best paper awards from the American Statistical Association in both Statistical Learning and Data Science and in Business & Economic Statistics. He has served as a mentor in the Google Summer of Code program for 7 years on behalf of the R Foundation for Statistical Computing and previously held an NSF

Graduate Research Fellowship. Prior to beginning his Ph.D. studies, he worked at Morgan Stanley as a quantitative analyst, focusing on derivatives pricing and financial risk management. He received a Bachelor's of Science in Engineering from Princeton University in 2008 and a Ph.D. in Statistics from Rice University in 2020.

Statistical Analysis of Multiple Network Structures and Signals

Graph signal processing (GSP) provides a powerful framework for analyzing signals arising in a variety of domains. In many applications of GSP, multiple network structures are available, each of which captures different aspects of the same underlying phenomenon. In this talk, we develop new statistical tools for data arising on multiple related graphs. First, we consider direct analysis of the network structure, developing a framework for principal components analysis of the networks themselves which identifies the most important patterns of changes in a series of networks. We then apply our method to the problem of change-point detection, identifying meaningful sharp “breaks” in the otherwise slow variability of a network over time. Second, we consider the analysis of signals arising on a given network, e.g., social media engagement with a news event: we develop a new framework for identifying the communities most responsive to a given signal and to identifying corresponding communities in different (non-overlapping) networks. Additionally, we provide a brief introduction to the regularized tensor decomposition framework underlying both these methodologies.



Robert Wible

Lt Col Robert Wible is an active duty officer in the United States Space Force. He obtained a BS in Mechanical Engineering at the Rochester Institute of Technology (RIT) in 2005 and a MS in Systems Engineering from George Washington University in 2014. He is a career USAF acquisitions officer with experience in operations, test and evaluation, intelligence, and space systems. He has served as a chief engineer and program manager for the National Geospatial-Intelligence Agency's (NGA) advanced analytics portfolio focusing on activity-based intelligence (ABI), multi-INT data fusion, and artificial intelligence (AI). At SMC, he led and negotiated an ACAT-I MILSATCOM joint program with Space Norway to deliver satellite communications to the Polar Regions. In context of the research presented at ICARS, he works directly for the Principle Investigator (PI) for NGA's research program, Dr. Jan van Aardt, to investigate lidar's ability to detect objects beneath forest canopies. He is currently a PhD student in the Chester F. Carlson Center for Imaging Science at the Rochester Institute of Technology, New York.

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Clark Wilson

Clark Wilson is a Professor of Geophysics in the Department of Geological Sciences at the University of Texas at Austin.

Core research competence: Analysis of time variations in Earth's gravity field and rotation and related geophysical causes. Affiliated with the University of Texas Center for Space Research since 1982.

Environmental Sources of Gravity Variations at a Mountain Site

NGA and other agencies routinely perform absolute gravity surveys in order to maintain geodetic control networks. In a typical absolute gravity survey, an absolute gravimeter (AG) is run for multiple days, repeating the free-fall measurement thousands of times, and providing a measure of gravity (g) about every 15 seconds. A major challenge is dealing with environmental sources of gravity change that contaminate AG measurements.

Our research group is developing techniques for removing environmental noise at the microgal and sub-microgal level, both during AG surveys and between repeat surveys, which are often separated by months or years. To develop and test these techniques, we have been collecting environmental and geodetic data at two field sites: at a site along the Texas coast and at a mountain site in West Texas. This presentation focuses on our work in West Texas, at McDonald Observatory. From nearly a year of continuous and high-precision gravity data from our superconducting gravimeter (SG), we are learning about the local environment, and are comparing a number of environmental models (solid Earth tide, atmospheric loading, ocean loading, and polar motion) to SG observations. The SG in this way is a screening tool to assess which environmental models may be locally tuned for reducing variance of AG observations. In addition, we are developing a local model of gravity change due to water storage change on the surface and in the vadose zone using data from multiple hydrologic sensors and a met station on site.

In upcoming work, we hope to host NGA's AG crew at McDonald Observatory, for a simultaneous AG and SG campaign. Additionally, NASA recently installed three GNSS receivers near the SG, which will allow us to examine possible vertical displacement influences on gravity change.



William “Will” C. Wright

LTC(P) William “Will” C. Wright is the Director of the Geospatial Information Science program at West Point, NY. LTC(P) Will Wright began his career as an Armor officer in Cavalry units. In his early career he deployed with 3rd Armored Cavalry to Bosnia and Iraq. After his Troop Command, LTC(P) Wright was selected into the Space Operations functional area where he served as a Missile and Space Domain Chief at NORAD. In that capacity he monitored and reported on events detected by strategic remote sensing systems. In 2007 he received his master’s degree in Geosensing Engineering and in 2017

he was awarded a PhD in Geomatics both from the University of Florida. He teaches remote sensing, advanced remote sensing, surveying, computer cartography, Geographic Information Systems (GIS) and Advanced GIS at the United States Military Academy. In 2018 he conducted a summer deployment to Djibouti where he was embedded with the National Geospatial-Intelligence Agency. His research interests include modeling signal loss in complex environments, photogrammetry, Global Navigation Satellite Systems (GNSS), Lidar, Remote Sensing and GIS.

Sensitivity Analysis of Varying Spatial Resolution on the Determination of Helicopter Landing Zones

This presentation explores the variation and accuracy of Helicopter Landing Zone (HLZ) footprints as determined by different spatial resolutions in the required data used in the calculations. This presentation will discuss (1) the automated methodology used for the calculation of multiple HLZs at varying spatial resolutions at three different geographic areas of the world, (2) the methods and results of ground truth in each HLZ, and (3) the initial findings and results. The study sites for the research include the military training areas at West Point, NY., Fort Carson, CO., Pinon Canyon, CO., and Fort Richardson, AK.



Eric P. Xing

Dr. Eric P. Xing is a Professor of Computer Science at Carnegie Mellon University, and the Founder, CEO, and Chief Scientist of Petuum Inc., a 2018 World Economic Forum Technology Pioneer company that builds standardized artificial intelligence development platform and operating system for broad and general industrial AI applications. He completed his undergraduate study at Tsinghua University, and holds a PhD in Molecular Biology and Biochemistry from the State University of New Jersey, and a PhD in Computer Science from the University of California, Berkeley. His main research interests are the development of

machine learning and statistical methodology, and large-scale computational system and architectures, for solving problems involving automated learning, reasoning, and decision-making in high-dimensional, multimodal, and dynamic possible worlds in artificial, biological, and social systems. Prof. Xing currently serves or has served the following roles: associate editor of the Journal of the American Statistical Association (JASA), Annals of Applied Statistics (AOAS), IEEE Journal of Pattern Analysis and Machine Intelligence (PAMI) and the PLoS Journal of Computational Biology; action editor of the Machine Learning Journal (MLJ) and Journal of Machine Learning Research (JMLR); member of the United States Department of Defense Advanced Research Projects Agency (DARPA) Information Science and Technology (ISAT) advisory group. He is a recipient of the National Science Foundation (NSF) Career Award, the Alfred P. Sloan Research Fellowship in Computer Science, the United States Air Force Office of Scientific Research Young Investigator Award, the IBM Open Collaborative Research Faculty Award, as well as several best paper awards. Prof Xing is a board member of the International Machine Learning Society; he has served as the Program Chair (2014) and General Chair (2019) of the International Conference of Machine Learning (ICML); he is also the Associate Department Head of the Machine Learning Department, founding director of the Center for Machine Learning and Health at Carnegie Mellon University; he is a Fellow of the Association of Advancement of Artificial Intelligence (AAAI), and an IEEE Fellow.

According to csrankings.org, Professor Xing currently ranks among top computer science (CS) professors worldwide, whose papers (in the most selective CS conferences of all disciplines) collectively have the highest (weighted) acceptance among all computer scientists in the US and global universities during 2010-2020.

Toward Knowledge and Structure-rich Text Generation

Generating coherent and accurate in-demand natural language is of ubiquitous use in practice and is a fundamental challenge in artificial intelligence. Until very recently, text generation research has been largely focused on benchmark-oriented tasks such as machine translation or image captioning, which relies on vast amounts of direct supervision data. However, these efforts remain primitive and academic from a real-world application point of view. Different applications require text-generation under various forms of complicated conditions, e.g., generating concise summary report from natural or surveillance images or videos, personalizing the reports, doing so with limited or dirty data, inadequate labeling or supervision, and opaque evaluation metrics, etc., which often lead to suboptimal performance, generating pale, irrelevant, or even inaccurate text.

In this talk, we will present our recent work on toward addressing these difficulties: (1) making better use of existing text data by structural manipulation or augmentation; (2) handling a wide range of experiences beyond text data, such as reward signals and knowledge graphs; (3) designing suitable and generalizable evaluation metrics; and (4) making standardized and easy-to-use toolkits to enable convenient composition of text generation models. We intend to adopt a modular approach for image to text translation, by pipelining the text generation system from our work so far with a symbolic image understand system to be built soon.



Dillon C. Yost

Dr. Dillon C. Yost is an Intelligence Community Postdoctoral Research Fellow at the Massachusetts Institute of Technology, where he is advised by Professor Jeffrey Grossman. His intelligence community advisor is Dr. Paul Kolb at IARPA. Dillon earned a bachelor's degree with honors in chemistry and mathematics from Berry College in 2014. He then attended the University of North Carolina – Chapel Hill where he was an NSF graduate research fellow, earning his Ph.D. in physical chemistry in 2019 under the direction of Professor Yosuke Kanai. His research interests cover a wide array of topics in computational

materials science including electronic structure theory, first-principles electron dynamics simulations, and machine-learning aided materials design.

Computational Investigation of 2D Materials for Electromagnetic Interference Shielding

Sophisticated surveillance capabilities, combined with the ever-increasing reliance on wireless communication, presents many challenges for information security. For secure locations where sensitive information may be handled, there is a need for materials that can selectively absorb in certain frequency ranges of the electromagnetic (EM) radiation spectrum. These materials could be used as window coatings that are visibly transparent and are simultaneously capable of preventing surveillance attempts, electromagnetic interference (EMI), and unauthorized transmission of information. With this need for tunable electromagnetic absorption, 2D materials such as graphene, transition metal dichalcogenides (TMDs), phosphorene, and others, show great potential. Here, we present the rational design of 2D materials for ensuring information security through the application of high-throughput atomistic simulations performed on high performance supercomputers. Using real-time time-dependent density functional theory (RT-TDDFT) and the Kubo-Greenwood method for electrical conductivity, we calculate both the optical and dc conductivity for a given chemical structure. This computational approach has allowed us to screen over 2,000 unique materials, a much larger chemical space than what is accessible via experiments. We identify trends that help us to understand the complex physics and chemistry at play. Additionally, we propose several novel 2D material candidates that could offer simultaneously higher transparency and EMI shielding efficiency than the current state-of-the-art.



Stella Yu

Dr. Stella Yu is the Director of Vision Group at the International Computer Science Institute, a Senior Fellow at the Berkeley Institute for Data Science, and on the faculty of Computer Science, Vision Science, Cognitive and Brain Sciences at UC Berkeley. Dr. Yu is interested not only in understanding visual perception from multiple perspectives, but also in using computer vision and machine learning to automate and exceed human expertise in practical applications. Her group is currently actively pursuing complex-valued deep learning, sound-vision integration, and actionable mid-level representation learning from

non-curated data with minimal human annotations. <http://www.icsi.berkeley.edu/~stellayu>

Actionable Representation Learning from Natural Data

To make machines and robots see the world like us humans, we need algorithms that learn from natural data which are open-ended and often long-tail distributed with sparse human expert annotations. Human vision is so flexible and effortless that I would attribute its power to mid-level representations developed from a perceptual organization process without external supervision. My goal in computer vision is to replicate that capability by learning a task-specific representation from natural data in a minimally supervised, data-driven fashion. Representation learning not only makes a vision system more generalizable to new data and task variations, but also provides data organization automatically for human analysts to act upon according to tasks at hand.



Simon Zwieback

Dr. Simon Zwieback is an Assistant Professor at the University of Alaska Fairbanks. He obtained a PhD in environmental engineering from the Swiss Federal Institute of Technology (ETH) Zurich, Switzerland, in 2016. He received his MSc degree in geodesy and geophysics from the Vienna University of Technology, Austria.

His research program strives to combine technical advances in remote sensing of high-latitude regions with an improved understanding of the rapidly changing Arctic. His primary research goals are to map ground ice contents on regional scales and to identify the drivers and controls of various types of permafrost degradation and stabilization.

Satellite-Based Mapping of the Susceptibility to Permafrost Terrain Instability

Permafrost conditions are changing across the Arctic, as evidenced by widespread observations of ground warming, deeper active layers, and increased prevalence of terrain instability. Terrain instability induced by the melting of ground ice poses a hazard to critical infrastructure and further impacts Arctic water resources and terrain maneuverability. We currently lack automated methods to reliably gauge the susceptibility to terrain instability on regional scales, thus limiting predictions of the susceptibility to permafrost-thaw-induced terrain instability for geospatial intelligence operations and infrastructure planning.

To address this knowledge gap, we are developing a remote sensing tool for estimating near-surface excess ground ice profiles from space. It exploits the intimate relationship between near-surface ground ice and remotely sensed surface subsidence. In exceptionally warm summers, ground ice that had previously remained perennially frozen melts and causes late-summer subsidence. It is this subtle precursor with which we will detect areas rich in top-of-permafrost ground ice that are thus susceptible to terrain instability.

To demonstrate the validity of the concept, we present simulation-based assessments and results from Northern Alaska. We find that the late-season subsidence in an exceptionally warm summer was 4–8 cm (5th–95th percentiles) in the ice-rich areas, while it was low in ice-poor areas (–1 to 2 cm; 5th–95th percentiles). The distributions of the late-season subsidence overlapped by 2%, demonstrating high sensitivity and specificity for identifying top-of-permafrost excess ground ice. The strengths of the tool include the ease of automation, the independence of costly ground observations, and its applicability to areas that lack conspicuous manifestations of ground ice.



Mark Zumberge

Dr. Mark Zumberge received a B.Sc in physics from the University of Michigan in 1976 and a Ph.D. in physics from the University of Colorado, Boulder, in 1981. He has been a research geophysicist and lecturer at the University of California, San Diego, since 1983, in the department of Scripps Institution of Oceanography. His research has included measurements of gravity on land and on the seafloor, the development of optical seismometers, and measurements of strain using optical fibers, both on land and on the seafloor.

Acquisition, Deployment, and Testing of an Absolute Quantum Gravity Meter for Hydrological Measurements and Adaptation to Seafloor Geodesy

We have acquired a new type of absolute gravity meter: the laser-cooled atom interferometer type, which is now commercially available from the French manufacturer MuQuans. Our research has three objectives: 1) test the instrument's accuracy, repeatability, robustness, and response to environmental conditions; 2) resurvey a number of locations in California previously surveyed with an absolute gravity meter to determine water table changes over the past three decades; 3) begin the process of adapting the quantum gravity meter to seafloor applications.

Compared to the existing free-fall methods, the quantum gravity meter promises higher accuracy, better robustness for continuous operation, and recoilless measurements (ground recoil is an effect that has prevented successful free-fall measurements on the seafloor). We have initiated a series of accuracy tests in the lab and plan to collect data in our cold vault. We also plan the collection of a long time-series at our geophysical observatory to search for correlations with other environmental factors, a re-survey of absolute sites in California established in the 1980s to gain ground water information, and an assessment of the steps needed to adapt the technology to seafloor use. If the instrument stands up to our series of experiments and deployments we anticipate an outcome that includes expanded use of absolute gravity to study water table changes and a roadmap to the establishment of absolute gravity sites on the seafloor. The utility of extending repeated absolute gravity measurements to the seafloor has been recognized for some time. The rate of uplift or subsidence near mid-ocean ridges or subduction zones could be determined, magma motions could be detected, the details of ocean-crust deformation could be established, and even sea level variations in the middle of the ocean, far from land based tide gauges, could be tracked. Few viable methods exist to detect long term vertical motions of the seafloor. The capability to measure gravity with 1 part per billion accuracy (corresponding to a height sensitivity of 3 to 5 mm) on the bottom of the ocean would truly be transformative to marine geodesy and geodynamics.