Duke | Wireless Intelligent Sensor Networks
IGERT WISeNet

Workshop on Wireless Intelligent Sensor Networks (WISeNet)

Duke University
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Presentation Abstracts and Biographies

IGERT INTEGRATIVE GRADUATE EDUCATION AND RESEARCH TRAINEESHIP

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NSF

Dr. Nisar Ahmed, Cornell University

"On Generalized Bayesian Data Fusion with Complex Models in Large Scale Networks"

Author(s): Nisar Ahmed, Tsung-Lin Yang, and Mark Campbell

Abstract: Recent advances in communications, mobile computing, and artificial intelligence have greatly expanded the application space of intelligent distributed sensor networks. This in turn motivates the development of generalized Bayesian decentralized data fusion (DDF) algorithms for robust and efficient sharing of complex information among autonomous sensor agents using probabilistic belief models. Although straightforward for scenarios involving static network topologies and simple belief models (e.g. exponential family pdfs), Bayesian DDF is significantly challenging to implement for general real-world applications requiring the use of dynamic network topologies and complex belief models, such as Gaussian mixtures or hybrid Bayesian networks. To tackle these issues, we first discuss some new key mathematical insights about exact Bayesian DDF (which requires tracking of common information among network nodes) and conservative Bayesian DDF via the weighted exponential product rule (which leads to lossy consensus-like fusion). These insights are then used to develop novel generalized DDF algorithms for complex beliefs based on mixture pdfs and hierarchical factors. Numerical examples, including a large scale multi-robot target search scenario, demonstrate that our methods lead to significantly better accuracy and computational costs over existing DDF approaches, and thus have great promise for enhancing the performance and capabilities of complex intelligent sensor networks.

Author(s) Biography: Nisar Ahmed received his BSE from Cooper Union in 2006 and his MS, PhD in ME from Cornell University in 2009, 2011. He received an NSF Graduate Fellowship in 2007 and the 2011 AIAA GNC Best Paper Award. He is a postdoc at Cornell and interested in estimation, sensor networks, machine learning, and human-robot interaction.

Tsung-Lin Yang received his BSEE from Walla Walla University in 2008 and MEngs. in ECE, CS and MAE from Cornell from 2010-2012. He is an engineer with TaggPic in Ithaca, NY and interested in robotics, machine learning, and computer vision.

Mark Campbell is Director of MAE at Cornell University. He received his BSME from CMU in 1990, and MS, PhD in Control and Estimation from MIT in 1993, 1996. He received a NASA award for the MACE experiment flown on STS-67, and several best paper and teaching awards. He is an Associate Fellow of the AIAA, ARC International Fellow, and Associate Director of the AACC board, and interested in autonomous vehicle estimation and control.

Dr. John J. Bang, North Carolina Central University

"Wireless Sensor Network for a Sustainable Ecosystem and Environmental Modeling"

Author(s): John J. Bang and Henry Joyner

Abstract: Most traditional monitoring techniques developed and practiced during the past several decades are well known for their validity and reliability. With the fast growing world populations and global urbanization process, however, we have reached a critical point where a new paradigm in exposure assessment technique needs to be developed and implemented for a sustainable practice for the protection of both environment and human health. The need for a paradigm shift is even higher when we consider the powerful influences of climate changes on fragile ecosystems and sensitive people. For fulfillment of their purposes in a new paradigm, any new exposure assessment systems in the future will need to carry at least the following three properties such as low operation cost, (near) real-time signaling capacity, and simplicity for an easy operation. In this presentation, a case study conducted by bi-national joint groups for spatial exposure analysis on PM2.5 levels in border town of El Paso, Texas and Juarez, Mexico will be presented to support the view that application of wireless sensor network in exposure assessment, is an over-due process and how wireless sensor network can be also beneficial in biomedical fields.

Author(s) Biography: Dr. Bang is a native of South Korea. His interest in understanding humanity helped him explore various activities that people often focus on, especially arts and music during his college years. His nature of enjoying an intellectual challenge in addition to the curiosity of getting to know some unexplored fields eventually led him to medical and engineering fields where he spent some years at the University of Illinois at Urbana-Champagin and University of Texas at El Paso. His current research focus is on ultrafine and nanomaterial in exposure and risk assessments and remediation perspectives. He would like to know more about various mechanisms behind exposure process and pathophysiology for maximizing preventive methods development.

Cassandra Carley, Duke University

"Features for Human Hand Tracking"

Author(s): Cassandra Carley and Carlo Tomasi

Abstract: We are developing a markerless approach to find the 3D pose and configuration parameters of a human hand from the depth data acquired by a Microsoft Kinect sensor. Our approach has two stages. An initialization algorithm first retrieves approximate parameters from a database, using features extracted from the 2D hand silhouette as indices. A second stage then refines these parameters by local optimization methods. This contribution focuses on initialization, and proposes a retrieval index that describes the 2D shape of a hand in terms of a union of overlapping disks that together cover the region bounded by the silhouette. Index features are constructed as fixed-length summaries of the geometry and topology of the union of disks.

Author(s) Biography: Cassandra Carley is currently a Ph.D. student in the Computer Science Department at Duke University and an IGERT WISeNet Fellow.

Mr. Itay Cnaan-On, Duke University

"Energy-efficient Simultaneous Wireless Telemetry and Node Localization of Distributed Sensor Networks"

Author(s): Itay Cnaan-On, Matt Reynolds, and Jeffrey Krolik

Abstract: Current sensor communication techniques offer high data rates and focus on minimizing the overall Bit Error Rate (BER) of a sensor data stream. However, these sensor communications currently provide very poor localization accuracy or resilience to wireless clutter. In order to overcome this technological challenge, I will draw from Sensing and Radar theory.

Sensing and radar theory have the advantage of excellent localization capabilities and resilience to clutter, however these techniques are not suited for carrying data. Combining this theory with the knowledge accumulated in communication theory can provide the framework that solves the technological challenge I have described.

In this workshop I will present a novel signaling technique developed for simultaneous sensor data telemetry and localization. Presenting a hybrid mathematical framework and a signal model that encapsulate both Communications and Sensing theories. In order to test this technique I will provide a performance analysis using benchmark tools which are commonly used in the separate fields such as signal-space constellation and Doppler-Range ambiguity surface.

Author(s) Biography: Itay Cnaan-On, received his B.S degree in electrical and computer engineering from Tel-Aviv University, Israel in 2010, and is currently a Ph.D. student in the ECE department at Duke University, Durham, NC. His research interests include array signal processing, ultra-wideband systems, sensor networks and localization.

Ms. Tierney Foster-Wittig, Duke University

"Experiment on Geospatial Monitoring of Air Quality and Pollutants: Locating Leaky Natural Gas Wells"

Author(s): Tierney Foster-Wittig

Abstract: Although natural gas is thought to have a smaller climate footprint than coal, the greenhouse gas (GHG) methane leaks during the production and the distribution of natural gas. Whether natural gas is an environmentally cleaner option depends on the amount of methane leaked; this is largely in debate due to a lack of direct measurement and accurate models. For that reason, air pollution concentration and meteorological field measurement data must be used to develop an accurate dispersion model which can identify the leaky wells and estimate the strengths of multiple sources.

In order to detect leaky wells, sensors collect instantaneous concentration data from a plume. For that reason, the plume we need to model is instantaneous with variable wind speed, wind direction, and atmospheric stability. An instantaneous plume is much more difficult to model due to its stochastic nature. Therefore, a major contribution of this research is to mathematically define the plume structure. This will then be used in a dispersion model to both locate and identify the source strengths of the leaky wells. This will allow EPA to monitor natural gas production and distribution sites on a regular basis.

Author(s) Biography: Tierney Foster-Wittig is currently a Ph.D. student in the Civil and Environmental Engineering Department at Duke University and an IGERT WISeNet Fellow.

Duke University, 2009-Present

University of Virginia, 2005-2009

Mr. Charles Freundlich, Stevens Institute of Technology

"A Hybrid Control Approach to the Next-Best-View Problem using Stereo Vision"

Author(s): Charles Freundlich, Philippos Mordohai, and Michael M. Zavlanos

Abstract: The increasing capabilities of mobile robots illuminate the need for robotic systems that are able to operate outside the controlled infrastructure of lab environments. Lab environments, equipped with e.g., Vicon systems, provide robots with continuous and precise position and orientation information. This information is not available outside the lab, where the robots should be able to localize themselves using on-board sensors. We address the problem of optimizing target localization accuracy using mobile stereo vision.

To solve this problem, we consider a single robot equipped with a stereo camera overlooking a group of stationary targets. The advantage of stereo vision, compared to the use of monocular camera systems, is that it provides both depth and bearing measurements of a target from a single pair of simultaneous images. Differentiation of these measurements provides an estimate for the uncertainty of the target's location. Assuming that noise is dominated by quantization of pixel coordinates and propagating this uncertainty to target coordinates, we obtain highly accurate estimates of the structure of the target location covariance matrix, which captures uncertainty. This is true for both the instantaneous uncertainty of one measurement and for fused uncertainty of the full sequence of measurements. Given such a sequence of measurements, we define the Next-Best-View (NBV) as the position and orientation of the stereo camera from where a new measurement of the targets minimizes their localization uncertainty.

Since controlling the NBV directly in the space of camera positions and orientations involves the solution of highly nonlinear differential equations, we propose a hybrid scheme that decomposes control into the camera-relative and global-world frames. First, we find the NBV in the camera-relative frame using gradient descent in the space of target locations. Then, we design motion potentials in the space of robot positions and orientations that realize the NBV. From this new position, the camera makes a new measurement of the targets that minimizes the fused target uncertainty, and the process is repeated until convergence of the target accuracies. In the proposed hybrid system, consecutive solutions of the NBV problem in the camera-relative frame constitute the switching signal in motion control. As a measure of collective localization accuracy we use either the average uncertainty of the targets corresponding to the centroid of their estimated locations or the uncertainty of the most poorly localized target.

Author(s) Biography: Charles Freundlich is with the Dept. of Mechanical Engineering, Stevens Institute of Technology, Hoboken, NJ 07030, USA.

Philippos Mordohai is with the Dept. of Computer Science at Stevens Institute of Technology.

Michael M. Zavlanos is with the Dept. of Mechanical Engineering and Materials Science, Duke University, Durham, NC 27708, USA.

Mr. Julio Herrera Estrada, Princeton University

“Network Design for the Deployment of Wireless, Low-Cost Sensors for Drought Monitoring”

Author(s): Julio E. Herrera Estrada, Dr. Justin Sheffield, Dr. Adam Wolf, and Nathaniel W. Chaney

Abstract: Low-cost devices with multiple sensors that communicate via the cell network provide a potential solution to the lack of in-situ measurements in many regions worldwide, and allow for more accurate drought monitoring. This work develops a framework to determine the optimal device-network needed to attain a certain level of accuracy in monitored variables, subject to the sensors accuracy and constraints due to feasible device placement locations, and costs.

A benchmark test case is done in the US, where we study the Little River Experimental Watershed in Georgia, for which a suite of high-resolution meteorological and land surface data sets are available. A simulation with the TOPLATS land surface hydrological model that was calibrated against available soil moisture probe and river discharge data is assumed as truth. Using knowledge of topography, vegetation and soil, different sensor device-network configurations are used to sample the meteorological and model output fields. The fields are reconstructed from the measurements and compared to the truth fields to determine optimal configurations. A real-world test case is also done in Zambia, which generally has few in-situ measurements and drought monitoring is highly reliant on satellite remote sensing and hydrological modeling.

Author(s) Biography: Julio Herrera Estrada is a first-year PhD student at Princeton's Department of Civil and Environmental Engineering in the program of Environmental Engineering and Water Resources.

Dr. Justin Sheffield is a Research Scholar at Princeton's Department of Civil and Environmental Engineering.

Dr. Adam Wolf is a Postdoctoral Research Associate in Princeton's Department of Ecology and Evolutionary Biology.

Nathaniel Chaney is a third-year PhD student at Princeton's Department of Civil and Environmental Engineering in the program of Environmental Engineering and Water Resources.

Mr. Xinghai Hu, Carnegie Mellon University

"An Algorithm for Testing k-Coverage Condition in WSNs based on k-NPVD"

Author(s): Xinghai Hu and Yan Dong

Abstract: Voronoi-based methods for k-coverage problem are not as popular as they should be. One of the main reasons is the difficulty for implementing diagrams. In this paper, we will propose a new method for testing k-coverage condition based on k-NPVD. We combine testing with construction of the diagram. Previous constructing methods are essentially based on Nearest Neighbor VD, and construction of a new diagram is done by repeatedly operating division and merging on old diagrams. This way of doing adds to complexity of programming. Unlike previous methods, ours does not rely on other VDs. Based on analysis of the diagram's properties, we represent the diagram as a graph and use breadth-first search for finding out all vertexes of cells and their corresponding kth nearest sensors. We also discuss the challenging boundary effects. Unlike previous methods, ours does not require the boundary to be regular in shape.

Author(s) Biography: Xinghai Hu is a graduate student in Electrical and Computer Engineering from Carnegie Mellon University. He received his bachelor degree from Huazhong University of Science and Technology, Wuhan, China. His research interest lies in machine learning and statistical signal processing.

Yan Dong (M 08) received the B.S. and M.S. degrees from Xidian University, Xian, China, and the Ph.D. degree from Huazhong University of Science and Technology, Wuhan, China, in 2007. She currently works in the Department of Electronics and Information Engineering, Huazhong University of Science and Technology, as an Associate Professor. Her research interests include particularly algorithms for highperformance wireless networks.

Dr. Caryl Erin Johnson, Introspective Systems LLC

"Scalable Sustainable Communities: A Cloud Base Approach to Autonomic Sensor Integration and Control"

Author(s): Dr. Caryl Erin Johnson

Abstract: In this paper we address the problem of adaptive sensor controls for large and scalable sustainable communities. Ideally the built environment is not a static thing; it evolves and adapts both because of changes to the environment and infrastructure as well as the cultural differences that emerge over time. We model an urban environment as a large collection of autonomic components - robots if you will that collaborate with reference to a global imperative. This imperative is framed in terms of carrying capacity with respect to the efficient use of all resources, water, energy, carbon, food, etc. Like an ecological system it adapts to change, not by centralized control, but by the collaborative interaction of the constituents. The solution is both simple and complex. Like the HADOOP/MapReduce approach used by the giant social media engines such as GOOGLE, LinkedIn, and Facebook to tame big data, we achieve scalability by bringing the analysis to the data not by bringing the data to a centralized processor. This approach avoids the scalability barriers faced by the current paradigm for centralized control of complex systems.

Author(s) Biography: Dr. Caryl Erin Johnson has pursued a career in science and science management, in government, academia, and the private sector over the past 30 years. Driven by a passion for modeling and simulation, system of systems engineering and computational intelligence and as a business leader she has lead innovative teams in government, academia, and corporate research. Her early work with the computer automation of regional and global seismic networks established the standard for such systems worldwide, and in its current form serves as the backbone of global seismic network processing for the U.S. Geological Survey in Golden, Colorado. She has over 20 scientific papers in reviewed professional journals and reference books, and is the author of a popular book on volcanoes. In her most recent position as a BAE Systems Engineering Fellow she provided leadership and scientific direction to management and business area directors related to evolving DOD applications of computational intelligence and virtual systems engineering as applied to robotics, machine vision, sensor fusion, cognitive interface technology, and mission performance optimization. She is presently co-founder and Chief Innovation Officer for Introspective Systems LLC, a company developing autonomic and adaptive controls for large scale complex systems with a focus on sustainable community optimization.

Ms. Karoline Johnson, Student Services Contractor to EPA's Office of Research and Development

“Applying sensor networks to evaluate air pollutant emissions from fugitive and area sources”

Author(s): Karoline Johnson, Bill Mitchell, Gayle Hagler, Brian Gullett, Eben Thoma, and Ram Vedantham

Abstract: Commercial low cost air quality sensors have become increasingly available in recent years. These sensors are of interest for air monitoring and emissions research. The low price point, small size, and low power consumption enable multiple sensors to be employed in dense network configurations. Sensor networks may be particularly attractive in complex source environments, such as fugitive emissions and area sources covering large spatial scales. EPA ORD researchers are assessing the application of these low cost sensors for in situ source emissions characterization, including laboratory and field scoping studies as well as dispersion model development. The sensors under evaluation include metal oxide, electrochemical, optical, and non-dispersive infrared sensors. Several sensors were recently tested alongside reference instruments at a forest fire study at Eglin Air Force Base, FL. The overall wireless network approach was successful and merits further assessment in source emission studies. Laboratory testing includes exposure chamber tests to observe sensor performance over a range of pollutant concentrations and under varying environmental conditions. Finally, in order to derive source information from a sensor network monitoring approach, a model called SEnsor NeTwork INtelligent Emissions-Locator (SENTINEL) is being developed which will graphically depict area concentrations from multi-node inputs of sensor data.

Author(s) Biography: Karoline Johnson is a graduate of North Carolina State University's Environmental Engineering Program. She is currently working as a student services contractor with EPA's Office of Research and Development, under the mentorship of Dr. Gayle Hagler. Her research focuses on developing emerging low cost sensors to evaluate air pollution source emissions.

Dr. Lorenzo Marconi, University of Bologna

“Design and Experimental Validation of a Control Strategy for a Miniature Quadrotor Aerial Vehicle”

Author(s): Michele Furci, Roberto Naldi, Ricardo G. Sanfelice, and Lorenzo Marconi

Abstract: This work focuses on the design and experimental validation of a feedback control strategy for a miniature quadrotor aerial vehicle so as to track a desired trajectory globally with respect to the initial conditions. The proposed approach is based on a cascade control paradigm in which the attitude and the position control loops play respectively the roles of the inner and of the outer loop. The attitude controller, in particular, has been designed using hybrid control techniques capable to overcome the topological obstructions affecting continuous time global stabilizing controllers. The obtained control law is then suitable to be employed in all situations in which the vehicle may have an arbitrary attitude as initial configuration, such as when the system is deployed by another aerial vehicle. The proposed controller has been validated experimentally by developing a prototype of quadrotor helicopter which has been equipped with sensors and computational hardware suitable to address a large variety of applications.

Author(s) Biography: Michele Furci graduated in 2012 in Automation Engineering from the University of Bologna. Since 2013 he is a Ph.D. student and member of the Center for Research on Complex Automated Systems CASY "Giuseppe Evangelisti".

Roberto Naldi is an assistant professor at the University of Bologna since 2011. His main research interests are nonlinear control and hybrid control with applications to unmanned aerial vehicles.

Ricardo G. Sanfelice is an Assistant Professor at the Department of Aerospace and Mechanical Engineering, University of Arizona. His research interests are in modeling, stability, robust control, observer design, and simulation of nonlinear and hybrid systems with applications to power systems, aerospace, and biology.

Lorenzo Marconi is an Associate Professor at the University of Bologna. His current research interests include nonlinear control, output regulation, control of autonomous vehicles, fault detection and isolation, fault tolerant control.

Mr. Matthew Ross, Duke University

“Spatiotemporal patterns of pollution in a river network”

Author(s): Matthew Ross and Emily Bernhardt

Abstract: In West Virginia, Mountaintop mining for coal is a type of surface mining that involves removing hundreds of meters of surface soil and bedrock to access shallow coal seams. This excess material is pushed into adjacent valleys and buries headwater streams in valley fills. The rapid weathering of previously unexposed bedrock causes streams that drain these valley fills to exhibit a dramatic increase in base cations as well as the toxic metalloid selenium. Consequently, the electrical conductivity increases from near 100 ¼ S/cm in streams with no surface mining influence to over 2000 ¼ S/cm in mined watersheds. The strength and consistency of this signal make conductivity a well-suited tracer to track the impact of mining with high spatiotemporal resolution. Using a network of sensors that measure stream depth and conductivity every 15 minutes, we have tracked patterns of conductivity during storms in a MTM-impacted river network. Upstream of a reservoir and confluence with an unmined stream, conductivity decreases with freshwater inputs from rainstorms, showing a pattern of dilution. However, downstream of the reservoir, the pattern is reversed, suggesting that mined streams may dominate the flow of water in the river network during storms leading to enhanced pollution export downstream.

Author(s) Biography: Matthew Ross is a second year PhD student in Biology and a WISeNet fellow.

Emily Bernhardt is a Associate Professor of Biogeochemistry in Duke's Biology department.

Mr. Keith Rudd, Duke University

“Optimal root densities in water limited ecosystems.”

Author(s): Keith Rudd, John Albertson, and Silvia Ferrari

Abstract: In water limited ecosystems, a plant's ability to survive and reproduce will depend on its ability to absorb water from its environment. This work, through simulation, has focused on finding the root density profile that maximizes transpiration.

Author(s) Biography: Keith Rudd received his B.S. in mathematics from Brigham Young University; an M.S. in applied mathematics from Northwestern University, an MEM from Duke University, and is currently a PhD candidate in the mechanical engineering department at Duke University.

John Albertson received his B.S. in civil engineering from SUNY Buffalo; an MBA in Finance from the University of Hartford; a Masters in hydrology from Yale; and a Ph.D. in hydrologic science from the University of California at Davis. He is currently the department chair of the Civil and Environmental Engineering department at Duke University.

Silvia Ferrari received her B.S. in Aerospace Engineering from Embry-Riddle Aeronautical University and her M.A. and Ph.D. from Princeton University in Mechanical and Aerospace Engineering. She is currently a Paul Ruffin Scarborough Associate Professor of Engineering and the director of the IGERT WISeNet program at Duke.

Mr. James Shaeffer, Northern Arizona University

"A Middleware-Based Approach to the Design of Interconnected Sensor/Actuator Networks"

Author(s): James Shaeffer, Matt Miller, and Paul G. Flikkema

Abstract: Sensor/actuator networks are becoming hierarchical, with wireless ad hoc networks interconnected via infrastructured wireless (e.g., the cellular network) and the Internet. This trend is being driven by new application domains, such as cyber-ecological systems. In these systems, a sensor/actuator network is part of a closed-loop geographically-distributed system capable of near real-time sensing and actuation of the physical environment. To manage the complexity of networked systems, various middleware-based approaches to architecture-based design have been proposed. Here we describe the use of the DataTurbine streaming middleware in interconnected sensor/actuator networks. DataTurbine enables rapid construction of networked ring buffer data stores. It enables management of real-time streaming data and, unlike publish/subscribe approaches, provides persistent local storage for resilience to unreliable links. DataTurbine has been used in diverse sensing and data acquisition systems; here we discuss its use in interconnected real-time sensor/actuator networks for closed-loop control scenarios. Using Java applications built from the DataTurbine API, interconnected networks can link deployed sensor/actuator networks and servers resources anywhere in the world. In this talk, we demonstrate closed-loop sensing, networking, inference, control, and actuation in a test-bed cyber-ecological system, and discuss challenges and future work.

Author(s) Biography: Jame Shaeffer is a graduate student at Northern Arizona University working towards a Master's of Science in Engineering. He currently works at the Wireless Networks Research Labatory at NAU, focusing on development of a cyber-infrastructure for streaming data from wireless sensor networks.

Matt Miller, president of Cycronix, is an independent consultant for computer network architecture, cloud computing, mobile device software development, and real time sensor systems. He is the inventor and developer of DataTurbine streaming middleware software.

Paul G. Flikkema received the PhD in Electrical Engineering from the University of Maryland, College Park in 1992. From 1993-1998 he was an Assistant Professor at the University of South Florida, and joined Northern Arizona University as an Associate Professor in January 1999, where he is currently Professor of Electrical Engineering. His current work includes research and education in energy-efficient embedded systems and networks, inference of the embedding environment, and wireless sensor/actuator networks for monitoring and control of environmental and ecological systems.

Ms. Ashleigh Swingler, Duke University

"A Mixed Integer Programming Approach to Sensor Path Planning"

Author(s): Ashleigh Swingler and Silvia Ferrari

Abstract: Mobile sensors have emerged as efficient, cost effective solutions to many environmental sensing problems, including the localization of fugitive pollutant emissions, flora population management, and the monitoring of endangered species. The primary objective of a mobile sensor is to fulfill a sensing objective, such as target classification. Recent efforts have been focused on determining optimal paths for a robotic platform with onboard sensors that maximize the information gain of the sensors and minimize the operational cost of the robotic platform. Although many techniques have been developed for robot path planning, they are not always directly applicable to sensor path planning problems. This paper presents an approach by which the sensor path planning problem can be formulated as a mixed integer program (MIP) that can be solved using commercially available software. Simulation results illustrate that the methodology developed is an effective approach to sensor path planning.

Author(s) Biography: Ashleigh Swingler is an IGERT Wireless Intelligent Sensor Networks (WISeNet) Fellow, pursuing a PhD degree in Mechanical Engineering and Materials Science (MEMS) at Duke University with a focus on environmental sensor path planning. Ms. Swingler is a member of the Laboratory for Intelligent Systems and Controls, and earned her M.S. and B.S. degrees in MEMS at Duke University in 2012 and 2010, respectively.

Silvia Ferrari is a professor of Mechanical Engineering and Materials Science at Duke University. She earned her PhD and M.A. degrees in Mechanical and Aerospace Engineering at Princeton University, and her B.S. from Embry-Riddle Aeronautical University. Prof. Ferrari is the director of the Laboratory for Intelligent Systems and Controls, and the director of the IGERT program on Wireless Intelligent Sensor Networks. Her research interests include optimal control, mobile sensor networks, neural networks, and dynamical systems.

Dr. Ram Vedantham, United Stated Environemental Protection Agency (US EPA)

"Hybrid Models to Isolate and Locate Sources"

Author(s): Ram Vedantham and Gayle Hagler

Abstract: With the ever increasing availability of high quality high time-resolution data, it is increasingly possible to extract more information about the nature and possible location of the sources that were hitherto lost due to low sensor density and highly averaged data. New appoaches are being developed to use the location of multiple sensors and the highly time-resolved data from these sensors to pinpoint sources of emission and possibly their strengths.

Author(s) Biography: Dr. Ram Vedantham - Works on model development for a variety of spplications including source apportionment, sector apportionment, etc.

Dr. Gayle Hagler is a environmental engineer/postdoctoral fellow in the US EPA Office of Research and Development, National Risk Management Laboratory, Air Pollution Prevention and Control Division (APPCD), Emissions Characterization & Prevention Branch (ECPB). Dr. Hagler completed her B.S. in Civil & Environmental Engineering, MSCE in Civil Engineering, and Ph.D. in Environmental Engineering at the Georgia Institute of Technology. Dr. Hagler's research has focused on near road air pollution, including characterization of vehicular emissions, field monitoring instrumentation development, and assessing mitigation opportunities.

Ms. Tiffany G. Wilson, Duke University

“Towards optimal placement and operation of soil moisture sensors based on land surface features and topography”

Author(s): Tiffany G. Wilson and John D. Albertson

Abstract: Soil moisture is an essential hydrological variable for modeling processes including runoff, evapotranspiration, and vegetation growth. However, heterogeneous surface features cause soil moisture to vary in both space and time. In order to accurately model soil moisture on a hillslope, extensive soil sampling must occur in order to obtain the soil hydraulic parameters. Wireless sensor networks allow us to obtain data over an extended period of time. When paired with a rain gauge, wireless soil moisture sensors can increase efficiency by only sampling with higher frequency during rain events. Is there a way to place soil moisture sensors on a hillslope without knowing the soil parameters in a way that will accurately capture the soil moisture dynamics? What is the best way to control sampling frequency? We seek to start answering these questions by performing numerical experiments on a theoretical hillslope with known hydraulic properties. Using these properties in the truth solution, we can use modeled runoff as a proxy for soil moisture accuracy when compared to the runoff that results from soil moisture measurements with varying placement and frequency schemes. These experiments can help inform the management of wireless soil moisture sensors when extended data collection is needed.

Author(s) Biography: Tiffany is a fourth year Ph.D. student in Duke's Department of Civil and Environmental Engineering and 2012-2013 WISeNet Fellow. In 2007, she completed her Bachelor of Science in Engineering at Princeton University, also in Civil and Environmental Engineering. Before starting graduate school, Tiffany spent two years working as an engineer at an environmental engineering and consulting firm in Fort Lauderdale, FL. Tiffany's research at Duke focuses on the interactions between vegetation, climate change, and water supply in regions with Mediterranean Climates. Her academic honors while at Duke include the Pratt-Gardner Fellowship and James B. Duke Fellowship.

Dr. Adam Wolf, Princeton University

"PULSE: The Princeton University Low-cost Sensor Effort"

Author(s): Adam Wolf, Ben Siegfried, Molly O'Connor, Kelly Caylor, Justin Sheffield, and Eric Wood

Abstract: Many research questions in ecohydrology, forestry and agriculture would benefit from the availability of ubiquitous sensing capabilities, particularly of biological responses to hydroclimatic forcing. We have initiated a workshop for the development of low-cost sensors, managed by microcontrollers, which transmit data over cellular networks for realtime applications linking large-scale models with appropriate data to constrain model states and parameters. This presentation gives an overview of the unique hardware, software, and communications challenges we have faced in the development of our embedded environmental monitoring system, given the requirements of (1) design modularity in hardware and software; (2) environmental ruggedness; (3) low cost; (4) long life and low power demand; (5) scientific quality data; (6) data integrity; (7) presentation of data to models or decision makers via an API.

We are engaged with a variety of applications of these data streams for modeling and decision support. Of particular interest are soil moisture and meteorological monitoring for the Princeton African Drought Monitor; crop growth monitors that could be linked to fine-scale Landsat observations; tree growth and mortality in response to water and heat stress; changing bioclimates of rare and endemic plants; and water management in basins with multiple users.

Author(s) Biography: A diverse cadre of ecologists and hydrologists engaged with developing observation-driven models, and observing systems to support them.

Mr. Xiaochi Zhou, Duke University

“Remote sensing estimation of water constituent concentrations in tidal systems: a case study”

Author(s): Xiaochi Zhou, Sonia Silvestri, John D. Albertson, and Marco Marani

Abstract: Shallow coastal systems, such as lagoons and estuaries, are experiencing accelerated ecosystem degradation largely due to increased anthropogenic pressure. Despite its importance, our abilities to monitor water constituent concentrations in shallow water environments at proper scales are still lacking. Remote sensing methods provide access to a wide range of spatial scales. However, most remote sensors are not suitable for shallow and optically-complex waters, mainly due to their low spatial and spectral-resolution. A further limitation is related with the uncertainties in the bottom optical contribution and the spatial distribution of sediment types. To overcome these constraints, we developed a remote sensing-based approach to map water constituent concentrations (i.e., suspended sediment, chlorophyll, and colored dissolve organic matter) in shallow lagoons, which integrates hyperspectral remote sensing data, a simplified radiative transfer model, and in-situ water quality measurements. First, we calibrate and validate key parameters of the model, such as bottom albedo and absorption/backscattering coefficients, by comparing remote sensing derived water constituent concentrations with in-situ data. We then determine the statistics of those parameters by applying a bootstrapping technique. This approach has been applied to the Venice lagoon (Italy) and shows consistent results between estimated and measured water constituent concentrations and their optical properties.

Author(s) Biography: Xiaochi Zhou is a Phd Candidate at Civil and Environmental Engineering, Duke University. Zhou is interested in soil moisture spatial variability; wireless sensor network; remote sensing of water quality assessment.

Sonia Silvestri is a Research Scientist at the Nicholas School of the Environment, Duke University. Dr. Silvestri is interested in remote sensing of shallow waters, salt marshes, and coastal vegetation.

John D. Albertson is a Professor and W. H. Gardner, Jr., Department Chair of Civil and Environmental Engineering, Duke University. Dr. Albertson's research interests include: surface hydrology and boundary layer meteorology; semi-arid vegetation dynamics; large eddy simulation of turbulence and turbulent transport; urban air quality.

Maro Marani is a Professor at the Nicholas School of the Environment, Duke University. Dr. Marani s research interests include: marsh ecogeomorphology; plant root biomass allocation; hydrological extreme events; eco-hydrological of mosquito dynamics.

Keynote Speakers

Sonia Martinez, PhD

Associate Professor
Department of Mechanical and Aerospace Engineering
University of California, San Diego

"Self-triggered computations for multi-agent systems"

Abstract:

Due to their cheap deployment, maintenance and robustness, mobile robotic platforms endowed with sensors are being proposed to close the loop in a variety of cyber-physical scenarios. However, their deployment poses numerous challenges due to their limited computing, communication, and control capabilities possibly restricted by environmental constraints. This has motivated a paradigm shift to a self/event-triggered approach by means of which algorithms employ scarce resources only when needed. In this talk, we discuss how this principle can be exploited in sensor coverage problems paying special attention to best-response dynamics for selfish agents.

Biographical Sketch:

Sonia Martínez received her Ph.D. degree in Engineering Mathematics from the Universidad Carlos III de Madrid, Spain, in May 2002. Following a year as a Visiting Assistant Professor of Applied Mathematics at the Technical University of Catalonia, Spain, she obtained a Postdoctoral Fulbright Fellowship and held appointments at the Coordinated Science Laboratory of the University of Illinois, Urbana-Champaign during 2004, and at the Center for Control, Dynamical systems and Computation (CCDC) of the University of California, Santa Barbara during 2005. From January 2006 to July 2010, she was an Assistant Professor with the department of Mechanical and Aerospace Engineering at the University of California, San Diego. In a broad sense, Dr Martínez' main reseach interests include networked control systems, multi-agent systems, nonlinear control theory and robotics. In particular, she has focused on the modeling and control of robotic sensor networks, the development of distributed coordination algorithms for groups of autonomous vehicles, and the geometric control of mechanical systems. For her work on the control of underactuated mechanical systems she received the Best Student Paper award at the 2002 IEEE Conference on Decision and Control. She was the recipient of a NSF CAREER Award in 2007. For the paper "Motion coordination with Distributed Information," co-authored with Jorge Cortés and Francesco Bullo, she received the 2008 Control Systems Magazine Outstanding Paper Award.

Jie Gao, PhD

Associate Professor
Department of Computer Science
Stony Brook Univiersity

"Geometric Greedy Routing In Wireless Sensor Networks"

Abstract:

We consider a sensor network embedded in a geometric space and greedy routing that forwards the message to a neighbor whose distance to the destination is the smallest. We consider the deformation of the network geometry using curvature flow and show that greedy routing on the deformed network have a number of desirable properties such as guaranteed delivery, traffic load balancing, multipath routing, and fast recovery upon node/link failures.

Biographical Sketch:

Jie Gao is an Associate Professor at Department of Computer Science, Stony Brook University. She obtained her Ph.D degree from Department of Computer Science, Stanford University in 2004 and her B.S. degree from the Special Class for the Gifted Young at University of Science and Technology of China in 1999. She spent the academic year 2004-2005 at Center for the Mathematics of Information, California Institute of Technology. She received the NSF CAREER award in 2006. She now serves as the Associate Editor for ACM Transactions on Sensor Networks and IEEE Transactions on Automation Science and Engineering.

Tutorial Sessions

Daniel J. Gauthier, PhD

Robert C. Richardson Professor of Physics
Department of Physics
Duke University

"Tutorial on Autonomous Time-Delay Boolean Networks"

Abstract:

In this tutorial, we will discuss the dynamics of networks consisting of nodes that take on and update their Boolean values (e.g.: □ ON/OFF□ and □ 1/0□) in response to the input signals from other nodes. Signals traveling along the links that connect the nodes propagate at a finite speed and hence experience a time delay. Furthermore, the nodes process information as soon as it arrives at the input, thereby operating autonomously. Such networks serve as an idealized model for gene regulatory networks, for example. In this talk, we will show that they can be used to investigate a wide range of physical and biological behaviors that go far beyond gene networks. Toward this end, we will present our recent work on realizing large experimental autonomous time-delay Boolean networks using electronic logic gates located on a reconfigurable chip known as a field-programmable gate array (FPGA). We will explain how to combine logic gates to approximate the behavior of neurons and phase oscillators, for example, which allows us to study synchronization phenomena, phase transitions, and chaos in networks. Finally, we will mention a couple of practical applications in signal processing (random number generation, radar, and neuro-morphic computing).

Biographical Sketch:

Daniel J. Gauthier is the Robert C. Richardson Professor of Physics at Duke University. He received the B.S. (1982), M.S. (1983), and Ph.D. (1989) degrees from the University of Rochester and completed a post-doctoral research associateship (1989-1991) at the University of Oregon. In 1991, he joined the faculty of Duke University as an Assistant Professor of Physics and was named a Young Investigator of the U.S. ARO in 1992 and the NSF in 1993. He was chair of the Duke Physics Department from 2005 - 2011 and is a founding member of the Duke Fitzpatrick Institute for Photonics. His research interests include: high-rate quantum communication, nonlinear quantum optics, single-photon all-optical switching, applications of slow light in classical and quantum information processing, and synchronization and control of the dynamics of complex networks in electronic and optical systems. Prof. Gauthier is a Fellow of the Optical Society of America and the American Physical Society.

Wilkins Aquino, PhD

Associate Professor
Department of Civil and Environmental Engineering
Duke University

"An Introduction to the Inverse Problems: Theory, Algorithms, and Applications"

Abstract:

Inverse problems arise when the response of a system has been observed/measured and either parts of the system and/or its inputs need to be inferred from these observations. Many important and challenging problems in science and engineering can be conceived as inverse problems. Examples of inverse problems include the characterization of the earth interior from measurements of scattered mechanical or electromagnetic waves, the localization of a contaminant source from measurements of concentration, the reconstruction of a blurred image, and the characterization of the mechanical properties of the human heart from ultrasound data, among many others. Inverse problems are oftentimes ill-posed in the sense that existence, uniqueness, and stability of solutions cannot be guaranteed. In this tutorial, we will study how to formulate inverse problems, survey current techniques for solving these problems, and regularization strategies (bring balance to the force!). The tutorial will consider theoretical, algorithmic, and practical aspects of inverse problems. Applications will include some of the most common types of inverse problems found in science and engineering: material, source, and shape identification.

Biographical Sketch:

Wilkins Aquino obtained a BSCE from Purdue Engineering in 1994. He holds a MS and a PhD in Civil Engineering from the University of Illinois at Urbana-Champaign. He worked as a consulting engineer in the Engineering Mechanics and Infrastructure Division of Simpson, Gumpertz, and Heger, Inc. in Waltham, Massachussets for one year before joining the faculty at Cornell University in 2003. He has broad interests in computational mechanics, including computational inverse problems and their applications in engineering and biomedicine, chemo-mechanics, machine learning in mechanics, multiscale problems, fluid-structure interaction, acoustics-structure interaction, and generalized finite element methods, among others. He is also a member of the fields of Applied Mathematics, Theoretical and Applied Mechanics, and Computational Science and Engineering at Cornell University.