4th Annual Meeting of the AFRL Mathematical Modeling and Optimization Institute

MEETING PROGRAM WITH ABSTRACTS

University of Florida
Research & Engineering Education Facility (REEF)
Shalimar, FL
July 25–28, 2016

Meeting Information

Registration

Registration is free and all meeting attendees must register. **All presenters have been automatically registered.** Non-presenting attendees can register by emailing the organizers at `mmo.meeting.2016@gmail.com` with your name and affiliation or stopping by the registration desk on-site. Registration material can be picked up on Monday–Thursday 8:30am–4:15pm in the UF-REEF lobby.

Coffee Breaks

Coffee breaks will be held at 9:45–10:00am and 2:30–2:45pm on Monday–Thursday in the UF-REEF lobby.

Luncheon

Lunch will be provided to the registered meeting attendees from 11:30am-1:00pm on Monday-Thursday in the UF-REEF lobby.

Internet Access

Internet access is available free of charge.
Network SSID: ufvisitor

Meeting Rooms

Sessions A and B - Auditorium
Sessions C1 and D1 - Auditorium
Sessions C2 and D2 - Room 117

Monday, July 25th

9:00 Opening Remarks by Vladimir Boginski (Auditorium)

9:00-9:45 Plenary Session A (Auditorium)

A Simplified Approach to The Regularization of Control-Constrained Trajectory Optimization Problems

Michael J. Grant, Assistant Professor, Purdue University

Abstract: Trajectory optimization problems, especially control-affine problems, often include constraints on the control. The features of these problems generally introduce numerical challenges that may prevent the construction of numerical solutions using optimal control theory. Traditional regularization techniques incorporate an intentional small error into the original problem such that a new problem is created with improved numerical conditioning. Often, the proper application of these traditional regularization techniques is problem specific and could introduce additional challenges. The use of trigonometric bounding functions, referred to as trigonometrization, enables the creation of a unified regularization approach that can be applied to a wide range of problems, including those of interest in aerospace. Trigonometrization enables the complexities of regularization to be abstracted away from designers to support rapid, high quality analyses. The ability of trigonometrization to overcome the major challenges associated with traditional regularization techniques will be highlighted. Additionally, the simplicity and improved capability of trigonometrization will be demonstrated using a wide variety of examples.

9:45-10:00 Coffee Break

10:00-11:30 Session B (Auditorium)

Challenges in Modeling of Inelastic Deformation and Damage in Titanium: Multi-scale Modeling and Validation

Oana Cazacu, University of Florida

Abstract: A study on plastic deformation and damage in titanium was conducted. The X-ray tomography data reveal that damage distribution and evolution in titanium is markedly different than for a FCC material. Theoretically, it is shown that only by modeling both the anisotropy and the tension-compression asymmetry in plastic behavior it is possible to realistically predict Ti behavior. For a smooth specimen under uniaxial tension, the model predicts that damage initiates at the center of the specimen, and is diffuse; the level of damage close to failure being very low. In contrast, for a notched specimen under the same loading it is predicted that damage initiates at the outer surface of the specimen, and grows towards the center of the specimen, which corroborates with XCMT data.

Role of Tension-Compression Asymmetry on Low Cycle Fatigue

Benoit Revil-Baudard, University of Florida

Abstract: The generally accepted view is that induced plastic anisotropy is the main reason for accumulation of axial strains during monotonic and cyclic free-end torsion. In this paper, analytical results and numerical simulations using an elastic/plastic model with yielding described by the isotropic form of Cazacu

et al. (2006) criterion and isotropic hardening point to another important cause of this phenomenon. It is shown that such phenomenon can occur in an isotropic material, a slight difference between the uniaxial yield stresses in tension and compression of the material leading to a build-up of inelastic axial strains during cyclic torsion at constant strain amplitude. It is demonstrated that the ratio between the uniaxial yield stresses in tension and compression dictates whether permanent shortening or lengthening of the specimen occurs. Furthermore, it is predicted that by axially preloading the material below its plastic threshold and then subject it to strain controlled cyclic torsion under constant axial load, the axial effects may be either reinforced or reduced. Thus, for any given isotropic material it is possible to estimate the value of the constant load and the strain amplitude that need to be prescribed in order to eliminate these effects.

Implementation of Surface Roughness in a Pseudo-Spectral Solver for Direct Numerical Simulation of Bypass Transition
Shanti Bhushan, Mississippi State University

Abstract: Transition from laminar to turbulent conditions is important in many engineering applications, and significantly impacts important flow quantities, such as drag or heat transfer. Engineering applications often involve bypass transition, which occurs due to the presence of strong disturbances, such as high free-stream turbulence, wall roughness, flow separation, pressure gradients. The authors current research is focused on the temporally developing direct numerical simulations (DNS) of flat-plate boundary layer transition for high turbulence intensities and pressure gradients, to understand the turbulence growth mechanism including inter-component turbulent kinetic energy (TKE) transfer and turbulence damping (shear sheltering), and evaluate/ identify flow parameters that can be used as a marker for turbulence onset/growth (Bhushan et al. 2016). Sample result showing the coherent vortical structures predicted during transition are also shown. The preliminary conclusions of the study is that pressure strain plays a vital role in redistribution of TKE from the streamwise component to the wall-normal and spanwise components, and its growth is responsible for the flow transition. The study identified that molecular diffusion to pressure strain time scale ratio (based on either total TKE or 2D streamwise normal plane TKE) normalized by Reynolds number (Re) can be used as a marker for turbulence onset and growth. The overall objective of this research is to extend the ongoing study to include surface roughness affects, to understand its role in the enhancement of turbulence generation (and transition), and further validate the time-scale marker. To achieve the objectives, a hybrid MPI/OpenMP based pseudo-spectral solver, which uses FFT along homogeneous streamwise and spanwise directions and Chebyshev's polynomial along the wall normal direction, will be extended to include surface roughness. The solver will then be applied for temporally developing DNS of boundary layer flow. The presentation will discuss the challenges for the extension of pseudo-spectral method for surface curvature, and propose a numerical approach to address the challenges.

11:30-1:00 Luncheon

1:00-2:30 Session C1 (Auditorium)

Modeling the Deformation Response of Hexagonal Metals Under Strain Path Changes
Nitin Chandola, University of Florida

Abstract: An accurate description of the deformation response of hexagonal metals under changing strain paths requires consideration of their strong anisotropy and its evolution with accumulated plastic deformation. In this paper, a viscoplastic self-consistent crystal plasticity model is used for modeling the room-temperature deformation of a hexagonal metal for a variety of loading paths. The model, used specifically to predict the deformation response of an AZ31 Mg sheet, shows good agreement between measured and predicted textures and macroscopic stress-strain response for the applied strain paths. Additionally, the interplay between slip and twinning and its influence on work hardening are well described by the model. Thus, it is shown that the model can predict with accuracy the deformation response of hexagonal metals for loadings involving stress path changes.

Effective Thermoelastic and Thermal Properties of Metal-Ceramic Composites with Spatially Tailored Microstructures

Phillip Deierling, University of Iowa

Abstract: This presentation is concerned with the accurate estimation of effective thermoelastic and thermal properties of metal-ceramic functionally graded materials (FGMs). Heterogeneous composites such as FGMs are often characterized by their macro-level spatially-dependent material properties. These features garner the ability to create structures with enhanced or desirable system response by coupling desirable attributes of each phase (e.g. thermal, mechanical, electrical, etc.) to create materials with overall improved efficiency through microstructural tailoring. For example, this unique class of material finds useful application in aerospace industries as multifunctional thermal barrier coatings (TBCs) and thermal protection systems (TPS). Here, metal rich interiors absorb structural loads while ceramic dominant exteriors protect underlying materials from the effects of rapid elevations in temperature, oxidation, ablation, etc. Estimation of effective spatial- and temperature-dependent material properties is accomplished using high-resolution artificially generated 2D and 3D microstructures of spatially varying materials with consideration of manufacturing defects or features such as porosity and voids. Using micromechanical based homogenization techniques and finite element analysis (FEA) of RVEs, effective properties are determined for various grading configurations. Models are evaluated over varying ceramic volume fraction content and wide temperature range. Results are verified by comparing to the tightest known analytical bounds and approximations and validated using experimental data available in literature for each respective material property. In the talk details regarding the RVE modeling and generation process for graded composites will be shown. Additionally, resulting effective properties of a titanium/titanium di-boride (Ti/TiB2) FGM will be discussed. Briefly, the application and optimization of FGMs will be highlighted as a multifunctional mechanical/thermal structure for use in a representative hypersonic vehicle. Preliminary thermomechanical and optimization results of this exercise will be provided.

Simulation of Thermal Ablation in Laminated Composite Materials with Finite Element Analysis

Yeqing Wang, University of Iowa

Abstract: Extreme heating environments experienced by hypersonic vehicles in flight present significant challenges in the design of ablative thermal protection systems. Given complete and accurate material properties, a successful numerical prediction of thermal ablation requires solving the chemical equilibrium equations as well as the conservation equations of mass, momentum, and energy. Current numerical techniques to solve ablation problems rely on finite difference methods using a moving grid system. However, these current numerical tools require users to greatly simplify the geometry due to the limitations of the finite difference method. In addition, users are commonly required to generate mesh and run the analysis manually. When compared to the finite difference method, the finite element method provides better representation for problems with complex geometries such as the leading edge of hypersonic vehicles. However, very few attempts have been undertaken to solve ablation problems using finite element methods, especially in commercial software. A recent approach to modeling thermal ablation with finite element analysis in ABAQUS utilizes an ABAQUS subroutine UMESHMOTION and the ArbitraryLagrangian-Eulerian (ALE) adaptive meshing technique. However, this approach is not applicable when the problem includes multiple material domains (e.g., laminated composite materials, which are potential materials for hypersonic vehicles). To address this limitation, we have developed a MATLAB-ABAQUS integrated element deletion computational procedure that allows the prediction of thermal ablation in multiple material domains. This presentation will show the verification of the proposed element deletion procedure. The verification is performed by comparing the predictions of the temperature and ablation histories of a thermally decomposing isotropic material obtained using the proposed element deletion procedure under various given recession rates to the corresponding predictions obtained using the approach with the UMESHMOTION subroutine and ALE meshing technique. In addition, an example of applying the proposed element deletion procedure to predict the temperature and ablation histories of a glass-fiber-reinforced polymer-matrix laminated composite panel due to a non-uniform high-intensity heat flux will be presented.

A Summary of High-Fidelity Numerical Studies of Flow Acoustic Resonant Interactions in Transitional Airfoils

Lap Nguyen, Embry-Riddle Aeronautical University

Abstract: Flow acoustic resonant interactions in transitional airfoils have been extensively studied experimentally for several decades. However, contradictions still exist between different views on the basic physical mechanisms involved. This work focuses on elucidating the physics of the phenomenon through summarizing several high-accuracy numericalstudies on selected transitional-flow regimes for NACA-0012 and SD7003 airfoils for which experimental measurements recorded strong flow-acoustic resonant interactions characterized by multiple-tone acoustic spectra. Numerical studies employ a 6th-order Navier-Stokes solver implementing low-pass filtering of poorly resolved high-frequency solution content to retain numerical accuracy and stability over the range of transitional flow regimes.

1:00-2:30 Session C2 (Room 117)

Relative Edge Optimization for Multi-Agent MAV Mapping

David Wheeler, Brigham Young University

Abstract: Pose graph optimization techniques solve for the most-likely vehicle trajectory given the history of measurements. Graph vertices represent the vehicle's pose throughout the trajectory with respect to a single coordinate frame while graph edges are trajectory constraints imposed by relative measurements sensed by the UAV. Due to nonlinearities, pose graph optimization approaches leverage the Gauss-Newton iterative method, repeatedly linearizing the system about an estimate and then applying an update using the gradient information. While generally effective, degenerative solutions, such as local minimum, are possible, especially when the initial estimate is far from the true solution. For example, UAVs in GPS-denied environments are susceptible to pronounced drift, causing the initial trajectory estimate to be arbitrarily far from truth, occasionally resulting in degenerative solutions. Conventionally, pose graph optimization techniques search for the optimal set of graph vertices to minimize measurement discrepancy. We propose searching for the optimal set of estimated graph edges to minimize measurement discrepancy. While global vertices can be arbitrarily far from truth due to compounding errors, graph edges always remain close to their initial measurement. We have derived the optimization update equations for this relative edge optimization (REO) approach and have demonstrated that it converges to the global optimum. REO is compared to existing state-of-the-art methods, using both simulated and hardware collected data, and is shown to converge in similar or fewer iterations. REO methods are also shown to be less likely to diverge. Applicability to multi-agent coordination is also demonstrated.

Guidance-Assisted Monocular SLAM Scale Estimation
Daniel Whitten, Texas A&M University

Abstract: Micro aerial vehicles (MAVs) could be used to autonomously perform tasks in search-and-rescue, reconnaissance, or infrastructure-monitoring applications. In these environments, the vehicle may not have access to GPS (e.g. building interiors, urban canyons) or GPS may lack accuracy or consistency. To solve this problem, researchers have investigated methods for simultaneous localization and mapping (SLAM) using on-board vision sensors, allowing vehicles to navigate in GPS-denied environments. In particular, SLAM solutions based on a single monocular camera offer low-cost, low-weight, and accurate navigation indoors and outdoors without range limitations. However, the position estimates of monocular SLAM are only accurate to a scale factor. Without an accurate way of determining the scale, the position estimates cannot directly be used for navigation. In this work, we fuse an on-board inertial measurement unit (IMU), ultrasonic rangefinder, and pose estimates from a monocular SLAM algorithm in a Schmidt extended Kalman filter (EKF). The EKF estimates the scale factor and the vehicle's altitude online while considering the uncertainty of the inter-sensor parameters. The vehicle is guided up and down in order to autonomously initialize the monocular SLAM algorithm. The motion continues until the scale estimate converges within a set uncertainty. Using this method, a MAV can reliably navigate using pose estimates from monocular SLAM by carrying out this process whenever the scale factor is uncertain. The method is evaluated using data taken from an experimental rig.

GPS-Denied Cooperative Navigation in Real-Time
Hunter Young, Oklahoma State University

Abstract: The ability for UAVs to properly navigate to a desired goal location is severely hindered during navigation through GPS-denied environments. As a result, it is important for the system to have an accurate estimated position. Previous work has shown to improve accuracy through the use of a multi-agent system, in combination with relative measurement data provided by other agents and expert-designed paths in a centralized EKF. This project aims to improve the capability of this cooperative navigation approach by further tightening the error bounds on the position estimate by investigating a model reduction approach, and further analyze the estimation performance on a real-world dynamical system in real-time, with the aim of moving towards a multi-agent UAV system.

It has been shown that the uncertainty in the estimated positions of multiple agents navigating in a GPS-denied environment can be bounded, and reduced, when using the inter-agent range available. Furthermore, it has been shown that the uncertainty can be further reduced depending on the choice of path to be followed, for each agent. However, these results were obtained with a batch Smoothing and Mapping (SAM)technique after the agents have completed their respective paths.Furthermore, there has not been any work done in developing a physical platform to test the path-planning algorithm in real-time.The goal of this project is to investigate the real-time estimation performance of an incremental SAM technique (iSAM2) while being implemented in a de-centralized manner on a real-world dynamical system.

Robust Multi-Sensor GPS-Denied Navigation

Daniel Koch, Brigham Young University

Abstract: A common approach for GPS-denied navigation is to utilize exteroceptive sensors such as cameras and laser scanners. These sensors, in conjunction with algorithms such as visual odometry and scan matching, provide measurements of the relative change in pose of the vehicle since some keyframe image or scan. Current state-of-the-art algorithms typically rely on only one such sensor. As a result, they are brittle to changes in environmental conditions such as lighting, structure, or clutter that may be encountered in the course of a mission. Alternatively, utilizing a suite of complementary sensing modalities increases the likelihood that at least one sensor will provide accurate measurements at any given time as the vehicle traverses its environment. This work presents an estimation framework that improves the robustness of GPS-denied state estimation to changing environmental conditions by fusing updates from multiple exteroceptive sensors. Full state observability is guaranteed by estimating the vehicle's pose relative to a local coordinate frame collocated with an odometry keyframe. A description of the general framework will be given, along with a summary of experimental results to date with a multirotor vehicle. Progress on current research into online detection and handling of incremental sensor degradation will also be presented.

2:30-2:45 Coffee Break

2:45-4:15 Session D1 (Auditorium)

Singular Value Decomposition for Rapid Simulation of a Hypersonic Vehicle

Ryan Klock, University of Michigan

Abstract: A reduced order model method based on singular value decomposition and correlation is developed to capture the nonlinear flight behavior of a hypersonic vehicle. A set of state space training samples are collected using the complex-step method and used to identify a set of ordered bases which describe the variation of the state matrices. Surrogate functions are used to relate these bases to the states and may be used to estimate state matrices beyond the training set. The dynamics of a hypersonic vehicle may then be rapidly simulated while preserving most behaviors of the full nonlinear system. The speed, efficiency, and accuracy of this method are compared against the University of Michigan High-Speed Vehicle code and classically linearized state space representations of the same hypersonic vehicle.

Fluid-Structure-Jet Interaction Modeling for Flexible High Speed Vehicles

Ryan Kitson, University of Michigan

Abstract: Reaction control jets are considered for a slender high speed vehicle to improve system performance. However, the jet interaction with the supersonic flow leads to complex flow structures around the vehicle. The jet interaction resultant force and moment may be significantly different from the jet thrust only. In addition, aggressive maneuvers will lead to large unsteady aerodynamic and inertial loads, structural deformation and a coupled fluid-structure interaction. An accurate analysis of the complete fluid-structure-jet interaction problem is required to understand the effect on vehicle performance and stability. In addition, simplified models are needed to facilitate flight simulations and control development of high speed vehicles with reaction control jets. A jet interaction model is developed to analyze the fluid-structure-jet interactions of a representative slender high-speed vehicle to enable simulations of the vehicle in flight. The model is developed based on previous theoretical and empirical work and is compared to Reynolds-averaged Navier-Stokes computational fluid dynamics (CFD) solutions of the vehicle. In addition, a multi-fidelity model is developed that leverages the basic understanding of the fundamental model with the accuracy of the CFD solutions.

Variable Fidelity Aerothermodynamic Modeling for Multi-Discipline Modeling of Hypersonic Vehicles

Emily Dreyer, Ohio State University

Abstract: The USAF desires hypersonic air-to-ground vehicle systems that have the ability to maintain precision and reliability in extreme environments. An inherent challenge is tracking and managing the associated strong, dynamic, fluid-structural and fluid-thermal interactions over extended durations, which requires multi-disciplinary computational frameworks that can expediently predict the unsteady aerodynamic pressure and heat flux in a coupled manner. This study outlines a computational fluid dynamics (CFD) surrogate approach that uses steady-state CFD to capture complex flow features and theoretical models to correct for feedback effects due to fluid-structural and fluid-thermal coupling for a generic hypersonic vehicle operating on a terminal trajectory. The steady-state CFD model is replaced with a data-driven Kriging model to reduce the computational effort. The steady-state component of pressure has shown significant improvement over shock-expansion theory for a complete hypersonic vehicle configuration. The unsteady components have been previously examined in the context of 2-D and 3-D lifting surfaces and panels, and will be extended to a complete hypersonic vehicle in this analysis.

Multi-Fidelity Unsteady Aerodynamic Modeling of Agile and Flexible High-Speed Vehicles

Dianne Zettl, Ohio State University

Abstract: The United States Air Force (USAF) seeks advanced supersonic air-to-air vehicle systems capable of extreme agility while reducing weight and volume (for internal carriage considerations). For such systems, an inherent crosscutting challenge is managing the associated strong, dynamic fluid-structural interactions; and successfully doing so necessitates consideration of these effects at the early stages of system design. This requires multi-disciplinary computational frameworks that can accurately and expediently predict the unsteady aerodynamic pressure. Computational fluid dynamics (CFD) can provide a high accuracy solution. However, such an approach is not yet amenable for incorporation at the early design stages of analysis. Classical engineering-level approximations are sufficiently expedient, but cannot provide sufficient accuracy for all required conditions. These general issues have motivated a significant number of studies on model reduction techniques that can harness the capability of high-fidelity flow modeling tools, while remaining computationally feasible for the design process. One promising approach in supersonic flow fields, where the fluid-structural coupling is typically quasi-steady, is to generate a surrogate model based on a combination of steady-state CFD and theoretical aerodynamics. Here, the steady-state CFD captures complex flow features, while the theoretical models are used to correct the steady-state loads for feedback effects due to dynamic fluid-structural coupling. In order to further reduce the computational effort, the steady-state CFD model is replaced with a data-driven surrogate model using Kriging. The objective of this study is to develop and assess the CFD surrogate approach for application to supersonic munitions operating on representative trajectories. This is accomplished by constructing surrogate models for a generic supersonic air-to-air vehicle configuration and benchmarking against unsteady CFD solutions. Representative operating conditions for the supersonic vehicle are above Mach 2, with AOA of up to 60 deg, and turning maneuvers above 20 g's. The present analysis includes generation and evaluation of a steady-state CFD surrogate and comparisons between unsteady Euler and CFD-enriched local piston theory for a rigid body pitch maneuver. Upcoming results include CFD surrogate load predictions in the presence of representative structural deformations and for the vehicle configuration operating on a representative trajectory.

2:45-4:15 Session D2 (Room 117)

Geometric Adjoining Methods in Indirect Trajectory Optimization

Michael Sparapany, Purdue University

Abstract: Trajectory optimization through indirect methods yields additional usable information about the optimal solution that is otherwise lost when using direct methods. Information about the problem is directly encoded into solution through the well-known indirect adjoining method. Further analysis of the indirect solution reveals that, due to its second-order nature, the optimal motion is described by symplectomorphisms of the phase space. This sophisticated formulation allows one to study the optimal solution in a geometric context, providing a deeper understanding of the optimal motion than the standard indirect formulation. The first contribution of this talk is to provide a unique method of encoding information into an optimal solution while retaining the underlying geometric structure. Algebraic conditions are rephrased as differential-algebraic constraints and are adjoined through augmentation of a system's canonical symplectic form, moving complex root-solving calculations throughout the trajectory to a single point on the boundary. This method is less restrictive than the indirect adjoining method and provides a means to analyze the geometric structure of practical aerospace design problems. The second contribution is to show how the geometric structure of problems can be directly utilized in numerical computations through the construction of geometric integrators. A large subset of geometric integrators, known as symplectic integrators, exist in the theoretical physics community. Their usage in standard indirect trajectory optimization is not straightforward due to the existence of control variables. These additional variables are adjoined to the phase space of an indirect problem, thereby enabling the use of symplectic integrators.

Navigation Based Path Planning Using Optimal Control Theory

Sean Nolan, Purdue University

Abstract: The presentation will cover the progress made toward developing a framework that uses indirect methods to solve navigation based path planning problems. Increasing the accuracy of state estimation is helpful in systems that do not have access to high precision navigational aids like GPS. Several previous studies have shown that modifying a vehicle's trajectory can significantly improve the accuracy of its state estimation. These previous studies primarily have used zero-order optimization methods, which have significant disadvantages because important gradient information is not used. A framework that uses optimal control theory is being developed in order to provide higher fidelity solutions to these problems with less computation time. Already the framework has found high quality solutions to some of these problems with performance comparable with, if not greater than, other state-of-the-art trajectory optimization solvers. A particular problem of minimizing the variance of the location estimate of a ground based vehicle that measures distance from a beacon has served a baseline example that can be used to study the characteristics of these problems. Current efforts are underway to extend this case to problems that include multiple vehicles or hypersonic systems. The discussion especially will focus on the insights gained that help to solve navigation path planning problems. It will also include what challenges lie ahead to solve more complex problems of this type and what may be done to overcome them.

Adaptive Gimbal Control and Fixed-wing Target Tracking

Jae Lee, Brigham Young University

Abstract: Unmanned air vehicles (UAVs) have become a popular platform for target tracking. For example, a single UAV may be tasked to track multiple moving targets. If the UAV is unable to keep all of the targets in the field of view of the camera simultaneously, it must decide where to fly and how to orient the camera

to best understand target locations. A customized pan-tilt gimbal has been built with encoders to provide precise azimuth and elevation angles. An adaptive gimbal-pointing scheme is developed based on pixel location of the target in the image plane. In addition, the UAV geolocates the target using an extended Kalman filter (EKF). The target's future location is predicted with some measure of uncertainty. This information feeds a UAV guidance law to generate a feasible trajectory that best facilitates target tracking. A single UAV tracking a single target is considered at present. A single fixed-wing UAV tracking multiple targets will be considered as future work.

Tuesday, July 26th

9:00-9:45 Plenary Session A (Auditorium)

From GPS and Google Maps to Spatial Big Data

Shashi Shekhar, Distinguished Professor, University of Minnesota

Abstract: Since public availability of Global Positioning System in the 1990s, Spatial Computing has enriched billions of lives via pervasive services (e.g., Google Maps, Uber, geo-tagging, check-in), ubiquitous systems (e.g., geographical information system, spatial database management system), and pioneering scientific methods (e.g., spatial statistics). These accomplishment are just the tip of the iceberg and there is a strong potential for a compelling array of new breakthroughs such as spatial big data, localization indoors and underground, accurate spatio-temporal predictive models, etc. For example, a McKinsey report projected an annual $600B saving from leveraging spatial big data (e.g., GPS trajectories, remote sensing imagery, geo-social media posts, etc.)

However, many fundamental research questions need to be investigated to realize the transformative potential. For example, how may location-based services survive GPS-jamming (or spoofing)? How can machine learning algorithms be generalized to address spatio-temporal challenges (e.g., auto-correlation, non-stationarity, heterogeneity, multi-scale), to scale up to spatial big data and to model geographic concepts (e.g., context, hot-spots, hot-features, doughnut-hole patterns)? For example, new methods are needed to analyze spatial and spatio-temporal data to interesting, useful and non-trivial patterns. This talk surveys some of the new methods including those for discovering geospatial hotspots (e.g., circular, linear, rings), interactions (e.g. co-locations , co-occurrences, tele-connections), detecting spatial outliers and location prediction along with emerging ideas on spatio-temporal pattern mining.

9:45-10:00 Coffee Break

10:00-11:30 Session B (Auditorium)

Nonlinear Coupled Thermoelastic Beam Vibration Model and Thermoelastic Equations of Motion

Yuri Antipov, Louisiana State University

Abstract: At high speed hypersonic regimes, aerodynamic heating becomes a major and extremely complicated problem. For example, an accurate modeling of high-speed flight during the atmospheric reentry that captures the effects of high temperatures in the shock layer, large aerodynamic heating of the vehicle and the chemically reacting gas surrounding the vehicle in addition to the classical aerodynamics requires employing several disciplines, including those of gas dynamics, aeroelasticity, thermodynamics, thermochemistry, molecular physics, and statistical mechanics. In this talk we analyze coupled thermoelastic effects on vibration of a beam as a simple model of a vehicle and employ the results to derive thermoelastic equations of motion.

Of interest is the following model. The ends of a beam ($0 < x < l, |z| < h/2$) are free, and temperature is prescribed on the beam surface. Thermally induced vibrations of the beam are governed by the nonlinear systems integro-differential equations

$$\frac{\partial^4 u_z}{\partial x^4} + \lambda_0 \frac{\partial^2 u_z}{\partial t^2} + \lambda_1 \frac{\partial^2}{\partial x^2} \int_{-h/2}^{h/2} \theta z dz = 0, \quad 0 < x < l, \quad t > 0,$$

$$\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial z^2} + \lambda_2 (\theta + T_0) z \frac{\partial^3 u_z}{\partial x^2 \partial t} = \lambda_3 \frac{\partial \theta}{\partial t}, \quad 0 < x < l, \quad -\frac{h}{2} < z < \frac{h}{2}, \quad t > 0,$$

subject to the initial and boundary conditions

$$\theta|_{t=0} = 0, \quad 0 \le x \le l, \quad |z| \le h/2,$$

$$\theta|_{z=\pm h/2} = \theta_{\pm}(x,t), \quad 0 \le x \le l, \quad \theta|_{x=0} = \theta_L(z,t), \quad \theta|_{x=l} = \theta_R(z,t), \quad |z| \le h/2, \quad t \ge 0,$$

$$\frac{\partial^2 u_z}{\partial x^2}|_{x=0,l} = 0, \quad \frac{\partial^3 u_z}{\partial x^3}|_{x=0,l} = 0, \quad t \ge 0.$$

Here, $\theta(x,z,t) = T - T_0$ is not necessarily small, $T(x,z,t)$ is temperature, $u_z(x,t)$ is the beam deflection, λ_j are the model parameters. We propose a numerically-analytical approach for the solution based on the method of integral transformations and successive approximations. Comparison of this nonlinear model with its linear coupled and linear decoupled counterparts is discussed.

Under the assumption that the vehicle vibration modes are available equations of motion governing thermoelastic deformations are derived in terms of the free-vibration mode shapes and modal coordinates. Impact of thermoelastic effects on a vehicle's aerodynamics is explored.

Modeling of Flapping Airfoils in Proximity to Walls for Lift and Thrust Generation

Alex Povitsky, University of Akron

Abstract: Isolated pitching and plunging airfoils have been extensively studied in literature including prior work of the author using high-order spatial and temporal discretization. The effects of proximity of sections of flapping wings to each other and to solid walls have received much less attention. The optimal spacing and program of motion of flapping foils can generate thrust instead of drug. Thrust generation studies of flapping wings in proximity to other wing(s) and/or walls are needed for micro air vehicles, marine propulsion and generation of hydroelectric power. A numerical approach must handle complex multi–body dynamics while avoiding use of body-fitted grids needed for traditional finite-volume computations, which would require domain re-meshing at all time steps. The adopted and tested in the current study computational approach is based on particle-based kinetic Lattice Boltzmann method (LBM). Commercial LBM-based CFD software XFlow has been adopted, validated and tested. The local level of refinement of the underlying lattice is selected to control the refinement in near-surface boundary layer and in the street of shed vortices behind the airfoil. Governing parameters of single and paired flapping airfoils investigated include thickness and profile of foil(s), amplitude of plunging, angular amplitude of pitching, phase difference between plunging and pitching, proximity to rigid wall and distance between foils in tandem.

On the Optimal Stackelberg-Nash Risk-Averse Control Problems

Getachew K. Befekadu, NRC and University of Florida

Abstract: In this talk, we consider a risk-averse control problem for diffusion processes, in which there is a hierarchy of admissible controls or decision-making processes with different cost functionals and risk-averse satisfactions. We assume that there is a "global" decision-maker, which is the *leader*, and there are n "local" decision-makers, which are the *followers*. Our approach, based on a Stackelberg-Nash optimization framework, the *followers*, assuming that the *leader* has made an admissible control strategy, look for a Nash equilibrium of their cost functionals (i.e., the criteria, associated with stochastic target problems, in which the *followers* are interested in). Then, the *leader* makes its final decision for the whole system based on a certain level of risk-averse satisfaction that is required to be achieved for the *leader* as a priority over that of the *followers'* target criteria. In particular, we formulate such a hierarchical risk-averse control problem using coupled *forward-backward stochastic differential equations* that allow us to introduce a family of time-consistent dynamic convex risk measures, based on backward-semigroup operators, w.r.t. the strategies of the *leader* and that of the *followers*. Moreover, under certain conditions, we establish the existence of optimal

Stackelberg-Nash risk-averse solutions, in the sense of viscosity solutions, to the associated hierarchical risk-averse dynamic programming equations. Finally, we remark on the implication of our result in assessing the influence of the *leader's* risk-averse satisfaction on the achievable targets of the *followers'* in relation to the direction of *leader-followers* information flow.

11:30-1:00 Luncheon

1:00-2:30 Session C1 (Auditorium)

Switched Control of Semi-Autonomous Vehicles
Michael McCourt, University of Florida

Abstract: While autonomous control has proliferated across a wide range of applications, many tasks require monitoring by a human operator that has the ability to switch to manual control as needed. This paradigm is often referred to as "human on the loop" to distinguish it from more active control in "human in the loop". It is important to guarantee safety for the human and reliability of these systems so stability is a primary concern. This presentation focuses on recent work applying the notion of passivity to this switched control problem. Passivity has been used in many applications to guarantee stability of systems and interconnections of systems. The notion has recently been extended to switched systems in a meaningful way. The application of interest is control of a robotic vehicle allowing both autonomous control and manual human control. The strategy is to allow the human operator to switch between manual control and autonomous control as needed. The feedback loop is analyzed and shown to be stable using passivity and switched system analysis. Finally, an example is provided to demonstrate the approach.

Leader-Follower Consensus with Unknown Control Direction
Chau Ton, NRC

Abstract: The paper considers leader-follower consensus of multi-agent networks with unknown control direction. Sliding mode control is used to achieve consensus tracking of multi-agent systems under fixed topology with the assumption that the position of the leader is known to a subset of followers. The proposed distributed control law assumes unknown sign in the control input matrix of the followers and does not require the knowledge of the leader's velocity. Lyapunov analysis is provided to show that if the directed graph of the network has a directed spanning tree, then sliding mode control law can guarantee consensus tracking. Simulations results are provided to show the efficacy of the proposed controller.

Coverage Control Based Effective Jamming Strategy for Wireless Networks
Zhen Kan, University of Florida

Abstract: A group of mobile jammers is tasked with disrupting the overall communication of a static radio network. The jammers are assumed to have limited jamming capabilities, such that the jamming effect is constrained to a disk area around the jammer. Radios within the jamming zone will be disrupted and the jamming intensity depends on the relative distance between the radio and the jammer. To disrupt the communication network, a dynamic coverage control based jamming strategy is developed, where the jammers coordinate their motion and cooperatively guarantee that every radio in the network is accumulatively disrupted up to a desired jamming level over time. It is further assumed that each jammer has a limited communication capability. Two jammers can only share jamming information when they stay within a certain distance. To ensure consistent jamming coordination, motion control laws are developed for jammers to perform effective jamming while preserving network connectivity among jammers. An appealing feature of the current work is the use of mobile jammers to dynamically disrupt the overall communication network, which enables cooperative jamming over large scale networks by using a limited number of mobile jammers.

Acceleration-free Nonlinear Guidance and Tracking Control of Hypersonic Missiles for Maximum Target Penetration

Siddhartha Mehta, University of Florida

Abstract: Guidance and control law design for missiles traveling at hypersonic speeds is an extremely difficult task due to the inherently coupled nonlinear nature of the system dynamics. The controller designs are further complicated by model uncertainty and unmodeled disturbances, which are inevitable in practical application. Beyond the challenges inherent in the system dynamics, additional complications arise in the design of hypersonic missile control laws, where terminal constraints are imposed in order to optimize target penetration. In this research, a robust nonlinear control technique is combined with an optimal control method to develop a control law for air-breathing hypersonic missiles in the presence of model uncertainty and unmodeled, nonlinear exogenous disturbances. The control law presented in this paper is designed to be computationally inexpensive, requiring no observers, online adaptive laws, or function approximators. One of the contributions of this research is detailed theoretical analysis of the performance characteristics of the proposed tracking control design. In addition, maximum target penetration is achieved by generating an optimal desired trajectory that incorporates terminal constraints in the cost function. Specifically, the trajectory optimization routine is designed to minimize angle of attack (AoA) and inertial angle of obliquity (AoO) at impact. A Lyapunov-based stability analysis is utilized to prove global asymptotic trajectory tracking, and high-fidelity numerical simulation results are provided to verify the practical performance of the proposed guidance law design.

1:00-2:30 Session C2 (Room 117)

Fast Computation of Large-scale Linear Dynamical Network Learning

Xianqi Li, University of Florida

Abstract: This paper concentrates on the fast computation of large-scale linear dynamical network learning from algorithmic perspective under the assumption that the dynamical system is modeled by multivariate time series. Corresponding algorithms are developed for computing the transition matrices, which guide the evolution of the dynamical networks, based on the correlation level of the explanatory variables. Moreover, to learn the dynamical network topology accurately, we also consider simultaneously estimating the transition matrix and the covariance structure. Furthermore, a more efficient algorithm is proposed for a convex optimization problem for handling the non-stationary time series. Numerical experiments show that the proposed algorithms outperform the existing methods in efficiency with the same or lower modeling error.

Weighted Sampling For Stochastic Optimization

Chenxi Chen, University of Florida

Abstract: We consider stochastic composite optimization problem, and propose a new algorithm incorporating weighted sampling method to improve the dependence on variance resulted in random sampling procedures. Our algorithm can also solve problems with unbounded feasible sets, and thus we do not need the preassumption of boundedness of feasible sets. For convergence criteria, through duality gap, we improve the measurement of the accuracy of approximate solution in terms of primal energy residual and feasibility violation. For bounded and unbounded cases, we both get the optimal convergence rate and obtain better practical performance than previous algorithms with uniform sampling. The numerical experiments shows the efficieny of our proposed algorithm.

Convolutional Sparse Coding on Image Representation and Classification
Zhijie Feng, University of Florida

Abstract: Aerial images are referred to photographs taken from fixed-wing aircraft, helicopters and Unmanned Aerial Vehicles (UAV), etc. Since being invented, aerial images find many of their applications in military such as reconnaissance , aerial mapping and automatic navigation. Thanks to the rapid development of technology, huge amounts of aerial images are produced over time which greatly raises the need of automatic processing of them. Convolutional sparse coding algorithm forms a natural prior for optimization problems that arise from image representation and image classification. Image semantic classification remains one of the most challenging problems in computer vision, pattern recognition and statistical learning. To this end, significant progresses have been made in this research area. My report is applying convolutional sparse representation to construct a model on Aerial images problem, then extend to the much larger training sets.

2:30-2:45 Coffee Break

2:45-4:15 Session D1 (Auditorium)

Sequential Max-Min Bilevel Linear Programming with Incomplete Information and Learning
Juan S. Borrero, University of Pittsburgh

Abstract: We present a framework for addressing sequential decision-making in the context of max-min bilevel programming, where a leader and a follower repeatedly interact. At each period, the leader allocates resources to disrupt the performance of the follower, who in turn minimizes a cost function over a set of activities that depends on the leader's decision. While the follower has complete knowledge of his problem, the leader has only partial information, and needs to learn about the cost parameters, available resources, and the follower's activities from the feedback generated by the follower's actions. We measure policy performance in terms of its time-stability, defined as the periods it takes the leader to match the actions of an oracle who has complete information of the problem, and study the performance of a class of greedy and robust policies. We show these policies are weakly optimal, eventually match the oracle's actions, and provide a real-time certificate of optimality. In addition, we study a lower-bound on policy performance based on the decisions of a semi-oracle, and provide numerical experiments that demonstrate that greedy and robust policies consistently outperform other benchmark, and perform reasonably close to the semi-oracle.

Critical Arcs Detection in Influence Networks
Colin Gillen, University of Pittsburgh

Abstract: The influence network class of problem models the propagation of influence (an abstraction of cascading beliefs, behavior, or physical phenomenon) in a network. Such problems have applications in social networks, electrical networks, computer networks, viral spreading, and so on. Given a set of seed nodes and the linear threshold (LT) model, our work proposes to determine which arcs (*e.g.* relationships in a social network) are most critical to the influence propagation process. NP-completeness of the problem is proved. Time-dependent and time-independent mixed-integer programming (MIP) models are introduced. An improved MIP-based exact algorithm and a heuristic are proposed, and computational results presented.

Assignment Problem for Drone Delivery Under Bounded Rationality

Guanxiang Yun, University of Central Florida

Abstract: In recently years, the using of drone delivery for the last-mile delivery become very popular. The drone delivery can reduce the delivery cost and time and also can increase the efficiency for the response to the customers' demands. Normally when people consider about the drone delivery assignment problem, they usually focus on the number of drones they use, the paths the drone will choose, the load for the drone to carry. But in our work, we will also introduce the influence of bounded rationality to the drone delivery problem. We supposed that each agent can also rent the drone from other agents to delivery its customers' demands if other agents have the plan to the delivery items for the path needed by this agent. Then one agent's utilities will be influenced by other agents' decision. We establish the mix Integer Linear Program (MILP) model to solve our problem.

Measuring Network Robustness Using Information Theory

Arsenios Tsokas, University of Florida

Abstract: We test a new method of measuring network robustness when facing a sequence of failures or attacks.We focus on attacks or failures consisting of removals of links. Most known measures of robustness fail to capture the removal of a single link of a network, however the topology of the network is altered after such an attack. Our approach resolves this problem by comparing the degree or the distance distribution before and after the removal of a single link. These attributes of the network change after the removal of a single link. We use the Jensen-Shannon divergence as a measure of the differentiation of a distribution after the removal of a link. We use the proposed methodology to explore the vulnerability of artificial networks against random and targeted attacks. We also use the proposed methodology on real examples to account for their ability to resist attacks.

2:45-4:15 Session D2 (Room 117)

Decentralized LQT in a Limited Information Environment

Clay Robertson, Auburn University

Abstract: A mutli-agent formation of autonomous vehicles is tasked to maneuver through an obstructed environment, following a set of sequential waypoints provided by a ground controller. The agents share a global performance index but the control laws considered herein are decentralized since the agents are unaware of the commanded trajectory, allowing them to only sense the states of their nearest neighbors. The ground controller shares a single link with the formation through the formation leader. Sensor data of each agent is processed locally using a Kalman filter so that the leader may be indirectly observed. This work developed a decentralized control strategy based on the desired response of the formation to a single exogenous input from a ground controller and the communication capabilities inherent to the previously established interactions amongst the unmanned agents. The controller allows an agent variable dependence on its leaders and followers, ranging from a leader-follower to a virtual-structure type architecture. In this application, these architectures act as a bound on a control continuum such that a leader shares a dependence on the state of its followers, and vice versa. The location of the leader in the topology elicits certain types of behavior from the formation in terms of its response to the exogenous input, thereby restricting the bounds of the allowable control to stabilize the formation. Balancing these constraints with the desired response of the network, as requested by the ground controller, the individual agents determine their own control using limited information of the formation state to best satisfy the wants of the user and the constraints of the graph topology, i.e. a global objective function.

A Reduced Element Map Representation For Path Planning And Obstacle Avoidance

Jinyoung Park, Auburn University

Abstract: Consider an agent traveling an obstructed environment following a global path determined by a user. The path may go through obstacles or there might be several pop-up obstacles on the path. As the agent follows the global path, it is required to find alternative paths to avoid unexpected obstacles on the path. Determining the alternative paths is local path planning in real-time. To do this local path planning, Rectangular map (R-map) is applied, which is a new map representation having reduced number of elements from the conventional occupancy grid map representation. The agent has obstacle detection sensors on-board, a grid map is acquired from it, and the empty grid elements in the map are integrated as the maximal size of rectangular cuboids. A newly created map consist of the empty cuboids in free space as the R-map, and the connections of the cuboids are to be computed. Since the cuboids are only in free spaces, the R-map is naturally suited for obstacle avoidance when a path is within the cuboids. Therefore, with the known agent's current location and global path, the R-map allows obstacle avoidance on the global path by moving along the empty cuboids. This path planning method is beneficial when the agent encounter unexpected obstacles such as moving vehicles, pedestrians or new structures which are not indicated in the global map yet.

3D Road Geometry Recovery and Ground Target Motion Prediction by UA Using a Single Camera

Yingmao Li, University of Texas at Dallas

Abstract: Ground target interception and visual object tracking are open problems that can be improved by predicting the future motion of the target. Knowledge of 3D road geometry can be used to predict the target trajectory more accurately. Existing approaches solve these problems using active perception sensors, which are much more expensive than a video camera. In this talk, we will focus on solving the dual problem of 3D road geometry recovery and ground target motion prediction using a single camera on a Unmanned Aerial System (UAS), which can provide a low-cost but effective solution for this problem.

Specifically, we will discuss our recent developed algorithm in mono-vision 3D road geometry estimation using a pair extracted road curves from an aerial image. For a given number of sample points on one road curve (e.g. lane markings, or road edges), this algorithm searches for the offset points on the parallel road curve such that the 3D projection of the cross tie between each pair of offset points are parallel to the ground plane, and the norm of each cross tie is minimum in the 3D space. The road geometry is then recovered using the assumption that the width of a road is a constant everywhere inside the FOV of the camera.

Finally, the trajectory of an object on a road will be predicted using an Extended Kalman Filter and the recovered road geometry. The simulation results show the good performance of our method. Additionally, we will present our work using the real world data from the existing database and show preliminary results. The future work will be discussed at the end of the talk.

Camera Pose Estimation Using Quaternions

Kaveh Fathian, University of Texas at Dallas

Abstract: We present a novel algorithm to estimate the rotation and translation between two camera views from matched feature points. Our approach is immune to a variety of problems that plague existing methods. Methods based on the Euclidean Homography matrix only function when all points are coplanar in 3D space. Methods based on the Essential matrix become degenerate as the translation between two camera views goes to zero. By formulating the problem using quaternions, the rotation and translation are recovered independently, and the algorithm eschews the shortcomings of the existing methods. We do not impose any constraints on the 3D configuration of the points (such as coplanar or non-coplanar constraints).

Investigations using both simulations and experiments have validated the new method and verified that the algorithm can be used in practical context. Noise and time comparison between the proposed algorithm and the existing algorithms establishes the merits of this new algorithm. Source code of this algorithm is available to public and can be accessed online.

Wednesday, July 27th

9:00-9:45 Plenary Session A (Auditorium)

Finding Critical Links for Closeness Centrality
Oleg Prokopyev, Associate Professor, University of Pittsburgh

Abstract: Closeness centrality is a class of distance-based measures in the network analysis literature to quantify reachability of a given vertex (or a group of vertices) by other network agents. In this paper, we consider a new class of critical edge detection problems, where given a group of vertices that represent an important subset of network elements of interest (e.g., servers that provide an essential service to the network), the decision-maker is interested in identifying a subset of critical edges whose removal maximally degrades the closeness centrality of those vertices. We develop a general optimization framework, where the closeness centrality measure can be based on any non-increasing function of distances between vertices, which, in turn, can be interpreted as communication efficiency between them. Our approach includes three well-known closeness centrality measures as special cases: harmonic centrality, decay centrality and k-step reach centrality. Furthermore, for quantifying the centrality of a group of vertices we consider three different approaches for measuring the reachability of the group from any vertex in the network: minimum distance to a vertex in the group, maximum distance to a vertex in the group, and the average centrality of vertices in the group. We study the theoretical computational complexity of the proposed models and describe the corresponding mixed integer programming formulations. For solving medium- and large-scale instances of the problem, we first develop an exact algorithm that exploits the "small-world" property of real-life networks, and then propose two conceptually different heuristic algorithms. Finally, we conduct computational experiments with real-world and synthetic network instances under various settings, which reveal interesting insights and demonstrate the advantages and limitations of the proposed models and algorithms.

9:45-10:00 Coffee Break

10:00-11:30 Session B (Auditorium)

An Accelerated Extended Cutting Plane Approach with Piecewise Linear Approximations for Signomial Geometric Programming

Qipeng Phil Zheng, University of Central Florida

Abstract: This talk presents a global optimization approach for solving Signomial Geometric Programming (SGP) problems. We employ an accelerated extended cutting plane (ECP) approach integrated with piecewise linear (PWL) approximations to solve the global optimization of SGP problems. In this approach, the constraints of an SGP problem in the logarithmic domain are separated into convex and nonconvex ones. The nonconvex constraints are converted to mixed-integer linear constraints through PWL approximations. The convex constraints are handled via an ECP method. We also use pre-processed initial cuts and batched cuts to accelerate the proposed algorithm. Numerical results show that the proposed approach can solve the global optimization of SGP problems efficiently and effectively.

Assessing User Engagement Capacity as a Driver of Reach of Online Health Platforms
Alexander Nikolaev, University at Buffalo

Abstract: The challenges of strategically growing online health platforms, and in particular, social support forums, are recognized by many practitioners and researchers. We present the work on measuring engagement and assessing it as a driver of platform reach, hypothesized to achieve growth via positive externality effects. We overview the game theoretic bases of quantifying engagement, viewing a platform's social capital as a cooperatively created value. We then analyze whether the new metric "engagement capacity" can be useful for predicting reach. The data from the forums of a large Health Forum informs the presented research

Ranking Academic Advisors: Analyzing Scientific Advising Impact using MathGenealogy Social Network
Vladimir Boginski, University of Central Florida & University of Florida

Abstract: In recent years, a lot of emphasis has been put on assessing scientists' productivity in terms of number and quality of their publications. Popular metrics of publication productivity include quantities based on an individual scientist's citation record (i.e., total number of citations, weighted citations, h-index, etc.), as well as "prestige" measures of a publication outlet (such as journal impact factor, 5-year impact factor, SNIP, etc.) However, all of these popular metrics do not take into account another very important aspect of the academic profession: advising and mentoring students. In this paper we analyze a network comprised of nearly 200,000 mathematicians, nodes in the network are mathematicians who have completed PhD, edges are established between an advisor of a PhD thesis and a student. Data were collected from the Mathematics Genealogy Project. We find the most prominent mathematicians using social network analysis metrics such as degree, closeness, decay and betweenness centralities. We propose an index to quantify the level of success of the scientist based on the network around her.

11:30-1:00 Luncheon

1:00-2:30 Session C1 (Auditorium)

Path Planning for Optimal Cooperative Navigation
Adam J. Rutkowski, Air Force Research Laboratory

Abstract: For many navigation scenarios, it is known that the accuracy of navigation state estimates depends on the path traveled, particularly when access to external navigation aids such as the Global Positioning System (GPS) is not available. In this work, we present a path planning method that attempts to minimize the navigation uncertainty of a pair of autonomous vehicles traveling from known initial locations to desired goal locations. For the scenario considered in this study, each vehicle has an onboard odometer for measuring relative changes in position and heading. The vehicles also have sensors for measuring the range between the vehicles. Navigation state estimates are obtained using a centralized batch factor graph approach implemented with the Georgia Tech Smoothing and Mapping (GTSAM) library.

In previous work on this problem, candidate vehicle trajectories were chosen from a restricted class of trajectories referred to as pseudo-zigzagging. An exhaustive search of all possible trajectories in this class revealed that the final position uncertainty could be reduced by a factor of 5 when compared with the case of each vehicle traveling straight to its goal location. In the work we present here, the trajectories are no longer restricted to such a limited class. Instead, each path is constructed from a small set of waypoints that may be placed anywhere. We have devised a method that takes an arbitrary set of waypoint locations and

adjusts their locations so that the resulting path meets travel time and maneuverability constraints. Using just 3 waypoints for each vehicle path, and applying a simple random search optimization algorithm to the waypoint locations, the final position uncertainty can be reduced by another factor of 3. Thus, we achieve a total factor of 15 reduction in position uncertainty when compared to the straight path (i.e. worst) case. Also, the results indicate that the final position uncertainty can be different for each vehicle. Furthermore, the navigation certainty does not necessarily improve with increased travel time. Thus, travel time should be considered a free parameter (i.e. the time constraint is not necessarily an active constraint).

As is the case for most practical nonlinear optimization problems, there is no guarantee that the results obtained in this work are globally optimal. Nevertheless, it is quite clear that path planning can be used to significantly reduce navigation uncertainty for the scenario under consideration.

Validating a Model For Detecting Magnetic Field Intensity Using Dynamic Neural Fields

Brian K. Taylor, Air Force Research Laboratory

Abstract: Several animals use a combination of the intensity, and direction of Earth's magnetic field as a part of their navigation sensor suite to accomplish tasks ranging from local homing to continental migration. The study of these remarkable behaviors has led to the postulation of different underpinning sensory and processing mechanisms. However, these magnetoreceptive mechanisms have yet to be directly identified or confirmed. Several researchers have proposed models aimed at understanding and explaining these mechanisms, including both a magnetite-based sense, and the chemically based radical-pair mechanism. These models have focused on, and generated insights into the physics of sensory transduction. However, they were not designed to explicitly connect the sensory signal to the nervous system. Also, some of these models were designed to be conceptual in nature for the purposes of offering insights into future physiological experiments. Using dynamic neural fields, a computational neuroscience tool that models nervous system information processing, the present work expands on this field by implementing a previously developed conceptual model for processing magnetite-based magnetosensory feedback. The conceptual model was built to generate thought-experiment-like inferences on, and propose physiological experiments for this mode of sensory feedback. The present work expands on this model through mathematical simulation testing. Results demonstrate the validity of the model's predictions, and in some cases, provide insights regarding the conditions under which these predictions may or may not hold. In particular, the results of this work demonstrate that a population of magnetoreceptors that are each only capable of sensing directional information can, as a whole, encode magnetic intensity. When multiple populations are analyzed, it is possible to encode both magnetic direction, and intensity, two parameters that several animals use in their navigational toolkits. In addition to the results, this work creates a framework that can be used to test both the current model, and other magnetoreceptor models. The present work can be used to make predictions and inferences regarding how proposed sensory mechanisms directly affect behavior.

Network Delay Modeling For Assisted Global Navigation Satellite System (A-GNSS) And Magnetic Field-Based Navigation

Grant Huang, National Research Council

Abstract: Nowadays, satellite-based positioning technologies (the U.S. global positioning system (GPS) and other similar global navigation satellite systems (GNSS)) have become a commonly used application that is used autonomously or integrated in various location based services (LBS). Standalone GNSS receivers perform well outdoor with a clear view of sky while assisted-GNSS (A-GNSS) and other hybrid solutions help receiver operations by receiving assistance data from wireless networks in signal challenging areas, such as urban canyon and indoor environments. However, positioning technologies are vulnerable to potential

security risks, such as meaconing, spoofing, and jamming threats, which are reported by the U.S. Department of Transportation. We provide a methodology for A-GNSS (e.g. U.S. GPS and Russian GLONASS systems) network delay modeling that is applicable to various simulation environments as terrestrial channels for A-GNSS deliver random timing delays, which may impact time-sensitive GNSS performance and operations. Additionally, we explore magnetic field-based navigation which can support or complement satellite navigation technologies when GNSS is unavailable or unreliable.

1:00-2:30 Session C2 (Room 117)

Modelling Social Influence

Abhinav Perla, University at Buffalo

Abstract: In this talk, we outline a model to explain the behavior of agents under social influence. We consider a network of agents who engage into a particular activity regularly, but stochastically. If the agents were to engage in the activity independently from each other, they would perform it at a given certain rate; however, as they observe their connected peers engage in the action, they experience social influence and are motivated to engage into the activity at an increased rate. The steady-state of the actions of these connected agents is modeled as a Markov Random Field, whose node and edge potentials are found such that the joint probability distribution accurately approximates to the continuous time steady state conditions. Through this work, we would like to gauge the impact of influence on people's actions in a new model of influence spread.

Distributed Coalitional Learning

Rahul Gopalsamy, University of Buffalo

Abstract: This work presents a variation of the matrix completion problem for situations where an ordering ofitems is assumed to exist (e.g., workers can be ordered by their ability to perform tasks correctly). Thus, the proposed methods extend beyond conventional categorization of items as similar ordissimilar. Consider a situation where agents (e.g., UAVs), with mounted sensors, are assigned totasks (e.g., to reporting on objects of interest) and report to a central authority. The matrix completion done at this authority allows for estimating the capabilities of the sensors and requirements of tasks in these dimensions, and thus, order them accordingly. From this learned space, one can judge which tasks each sensor can successfully perform. This work also explores a possibility for distributed learning in the presence of several authority nodes. In such anenvironment, knowledge transfer amongst the source nodes occurs in a decentralized peer-to-peer manner without the original data being exchanged. We therefore seek to investigate, through decentralized learning: first, the possibility of a convergence to consensus after communication between all the source nodes, and second, methods to expedite convergence by controlling the order of communication between the source nodes.

A Continuous-Time Actor-Oriented Model for Decentralized Communication Network Formation

Anastasia Nikolaeva, University of Buffalo

Abstract: The present research aims at making new advances of earlier developed models for network formation in a decentralized manner to maintain sustained and reliable exchange of information. The use of messages as actionable information separates the present research from earlier developments in actor-oriented modeling. Each agent pings connected peers according to a Poisson process with a given rate; the ping prop-

agates through the network an absorbing random walk. The system is modeled as a continuous-time Markov Chain, where the agents stochastically build/revise a network to strategically embed themselves into the network for efficient information reception. The agents assess their network position quality by the times that they last heard from their peers. The model is structured so as to permit an analytical parametrization similar to actor-oriented models developed in social network analysis field.

2:30-2:45 Coffee Break

2:45-4:15 Session D1 (Auditorium)

On Landscape Graphs of Large-Scale Search for Multi-Sensor Multiple Target Tracking
Alla Kammerdiner, New Mexico State University

Abstract: In the U.S. Air Force applications, targets tracked with multi-sensor systems are obscured by the presence of false alarms or clutter. The data association must be done to determine which measurement among those that are detected should be assigned to update each track. The multidimensional assignment problem (MAP) provides a general framework for solving data association including track initiation and updating. The application of search algorithms on an instance of a combinatorial optimization problem, such as the MAP, produces a directed graph representation of its landscape. In this talk, we study the landscape graph of our recently proposed large-scale search for this computationally intractable problem. To better understand the characteristics of the landscape formed by this new search, we compute landscape graphs for various instances of the MAP produced byGrundel-Pardalos generator. We build and analyze graphs for moderate-sized problem instances. We describe the graphs produced by the new algorithm and their characteristics, and discuss the implications for restart strategies for solving instances of medium and large-sized MAPs.

Identifying Resilient Structures In Networks: A Two-Stage Stochastic Optimization Approach
Maciej Rysz, NRC & University of Florida

Abstract: We propose a two-stage stochastic programming framework for designing or identifying "resilient", or "repairable" structures in graphs whose topology may undergo a stochastic transformation. The repairability of a subgraph satisfying a given property is defined in terms of a budget constraint, which allows for a prescribed number of modifications so as to restore its structural properties after the observation of random changes to the graph's components. A two-stage stochastic programming model is formulated and is shown to be NP-complete for a broad range of graph-theoretical properties that the resilient subgraph is required to satisfy. A general combinatorial branch-and-bound algorithm is developed, and its applicability and computational performance is illustrated on the example of two-stage stochastic maximum clique problem.

Risk Averse Weapon-Target Assignment Problems
Konstantin Pavlikov, University of Florida

Abstract: The classical Weapon-Target Assignment (WTA) problem seeks to find an optimal assignment of weapons to targets that maximizes the expected (weighted) number of destroyed targets and solution methods significantly rely on the assumption that weapons destroy targets independently of each other with certain probabilities. This study recognizes that there can be two types of uncertainty about a missile of a certain weapon type to fail to destroy a target: (i) a missile itself is destroyed on its way to the target and

(ii) given that a missile reaches the target, it fails due to other reasons, e.g., malfunction, target protection, and so on. The first objective of this study is to separate these uncertainties, introduce specific assumption on each of them, and then incorporate them jointly in a model. The second objective of this study is to employ recently developed risk averse generalizations of the maximum expected covering location problems in order to create a wider class of risk averse WTA models.

Scalable Communication for Parallel Optimization
Oleg Shylo, University of Tennessee

Abstract: High performance computing systems are readily available to optimization experts in industry and academia, providing tools for solving optimization models of unprecedented scale. The objective of this research is to establish theoretical models that capture communication in parallel optimization algorithms. In particular, we focus on communicative algorithm portfolios, where a group of optimization algorithm works in parallel and shares information about the search process. We explore the structure and content of scalable communication, accounting for algorithm dynamics and communication overhead.

2:45-4:15 Session D2 (Room 117)

Vision-Based Control with Unknown Time Varying State Delay and Known Time Varying Input Delay with NN based Delay Estimate
Indrasis Chakraborty, University of Florida

Abstract: The objective of this research is to design a controller for a vision based system with state and input delay and to estimate the delay magnitude based on a Neural Network (NN) adaptation scheme. Time delay is a prevalent issue in a broad class of problems, mainly subcategorized as state delay and input delay. Vision based systems, for example, a sensorless missile navigation and guidance system, can experience state delay resulting in the time that it takes to capture an image and perform image processing. Image feedback is often used for the camera-to-hand problem, where the camera is used to view and provide feedback information to an agent. For some applications sensing and control are co-located and the controller is applied to the actuators of the agent through a network connection. In these cases an input delay is present. A partial differential equation-based robust controller is designed such that the control input varies with both time and a spatial variable. The designed controller features gains to compensate for the delay and delay derivative independently and because of the separation of the delay term outside the control input, a NN based estimation scheme is used to estimate the unknown state delay magnitude. A nonlinear mapping is used to transform the non-compact time interval to a compact set, to facilitate the use of NN. A novel Lyapunov-Krasovskii functional is used in the Lyapunovbased stability analysis to prove uniform ultimate boundedness of the error signals. Numerical simulation results illustrate the performance of the proposed robust controller and estimates the unknown state delay magnitude.

Utilizing Regional and Local State-Following Approximations for Online Approximate Optimal Regulation
Patryk Deptula, University of Florida

Abstract: As we seek to engineer more intelligent systems, opportunities to optimize them in real-time while ensuring stability and safety in the presence of uncertainty presents a challenge. Optimal control is a method which associates a cost with control actions and has been applied to a wide range of applications ranging from engineering systems to financial markets and medical technologies. Being able to learn optimal control

policies and minimize the cost of a control action, while also dealing with uncertainty, is a fundamental challenge of exploration versus exploitation, and in autonomous systems optimal behavior is necessary for efficient task execution. A technique that has been successfully implemented in deterministic autonomous systems to solve optimal control problems is called adaptive dynamic programming (ADP). The value function, which is the solution to the Hamilton-Jacobi-Bellman (HJB) partial differential equation, is generally infeasible to compute. However, parametric methods, such as Neural-Networks (NNs) are utilized in ADP to approximate the value function, which is used to compute the approximate optimal control policy. In optimal regulation problems, the goal is to regulate the state to a neighborhood of the origin. A semi-global model-based reinforcement learning (SGMBRL) approximation method has previously been shown to successfully approximate the value function over a compact set of the origin. However this method is limited as it only ensures approximation over a compact neighborhood of the origin. To mitigate this limitation, a method that trades global optimality for computational efficiency called the state-following (StaF) approximation method has been used to approximate the value function within a neighborhood of the state. Instead of approximating the value function over the entire operating region, the operating domain is split into two parts. While the SGMBRL method is employed to approximate the value function in a neighborhood the origin, the StaF-based method can be utilized to maintain stability by approximating the value function within a region of the state. Therefore, once the state enters a transition region, the SGMBRL approximation can be used to regulate the system to the origin.

Autonomous Herding of Uncontrolled Fleeing Agents with Switching Between Multiple Targets

Ryan Licitra, University of Florida

Abstract: A controller is developed for herding, i.e., using directly controllable agents to influence the states of target agents which are not directly controllable. In the herding problem, uncontrollable agents can be considered to be targets, while herders are agents that can be directly controlled. In these scenarios, one approach is to model interactions between the herder and target agents, and design a control law for the controllable herder such that the herding task is accomplished. This is a unique problem in the sense that in combines the notion of herding, which is largely approached from a heuristic perspective, with a game theory-like pursuit and evasion problem. A switched systems-based analysis is employed to determine how the herder will handle scenarios with multiple fleeing targets.

Decentralized Motion Control to Achieve Robust Multi-Agent Networks

Zachary Hutcheson, University of Florida

Abstract: Networked systems are widely used across a number of applications domains, including military, search-and-rescue, and telecom. However, if a network is not carefully designed, the failure of a single connection in the network could result in the inability of large parts of the network to communicate. Motivated by the desire to increase network robustness against such failures, this presentation explores the use of graph-theoretic and switching techniques in a system of mobile agents to result in an augmented random regular graph structure. Regular graphs have desirable robustness properties, and so by exploiting this,networks can become more resistant to communications failure, whether that is caused by adversarial jamming, hardware failure, or environmental interference. The main contribution of this work is the development of a motion control law, coupled with a link deletion protocol, which achieves almost-sure convergence to an augmented regular graph for a system of networked mobile agents.

Thursday, July 28th

9:00-9:45 Plenary Session A (Auditorium)

Assured Autonomy for Agents Operating in Contested Environments

Warren Dixon, Professor, University of Florida

Abstract: Autonomous systems have become one of the top research and development focus areas for the Department of Defense. This priority focus is motivated by the fact that autonomous systems can yield scaled force projection with economic advantages against adversarial capabilities in future contested missions. Smaller-scale man portable/launchable autonomous vehicles can provide unique tactical advantages such as localized munitions delivery and intelligence, surveillance and reconnaissance (ISR). Such tactical missions are typically executed in hostile/contested environments motivating the need for advanced functionality in a small footprint. The fact that such vehicles may be operated in contested environments motivate the need for adaptive response and time/fuel optimal behaviors. Moreover, the use of a network of small vehicles with coordinated behaviors can expand the set of mission objectives of small autonomous vehicles (e.g., timed/coordinated delivery of small munitions to yield larger effects, wider ISR coverage in reduced time). To facilitate such advances, this seminar will focus on assured autonomy through advances in autonomy, sensing, cyber security, and information flow in networks.

9:45-10:00 Coffee Break

10:00-11:30 Session B (Auditorium)

Theoretical Advances and Practical Algorithms for Adaptive Autonomy in Contested Environments

Girish Chowdhary, University of Illinois at Urbana-Champaign

Abstract: Unmanned Aircraft (UA) have already seen deployment and success in diverse battle arenas, however, most UA operation remain semi-autonomous and heavily supervised. This operational paradigm is not well matched with the emerging needs of conflict, including higher threat levels, stringent communication constraints, and dynamic, agile, and deceitful adversaries. In this talk, I will present recent advances by my group towards UA that serve as co-fighters in complex, asymmetric, and nonstationary battles. The focus will be on overview of new data-driven modeling and distributed monitoring paradigms for adaptive autonomy in uncertain spatiotemporally varying environments. On the data-driven modeling front, I will present a nonparametric modeling paradigm termed as Evolving - GP (E-GP), being designed for learning both abrupt and long-term changes in spatiotemporally evolving systems. On the distributed inference front, I will also present inference and UAS based sampling algorithms for distributed teams of mobile and static agents in the presence of cyber-physical constraints, such as limited communication range or flight-endurance. The new models and algorithms have been validated on real-world large datasets, and are expected to lead to autonomous UAS for modeling and monitoring massive scaled dynamically changing evolving phenomena. To illustrate this point, I will present results from our real-time Hardware-in-the-Loop simulator for UAS and flight-test results.

Cheap Approximate Localization Using FM Radio
Piyush Kumar, Florida State University

Abstract: It is hard to imagine a world without GPS. Unfortunately, GPS might be jammed, spoofed or become unavailable. In this talk, I will present a coarse and passive localization system for GPS-denied environments. Our system is based on a cheap software defined radio (SDR) costing $10, which is used to listen to broadcast signals from local FM Radio stations. We show that the hardware and associated algorithms are capable of localizations with average errors of less than 5 miles, without requiring a fingerprinting or crowd sourcing approach.

Comparison Between Stochastic and Simulation Based Optimization of Reactive Burn Models for Energetic Materials
Robert J. Dorgan, Air Force Research Laboratory

Abstract: TBA

11:30-1:00 Luncheon

1:00-2:30 Session C1 (Auditorium)

High Communication Efficiency Subgraphs
Vladimir Stozhkov, University of Florida

Abstract: We introduce a new clique relaxation model based on the notion of communication efficiency $\mathcal{E}_f(G)$. The communication efficiency represents a universal connectivity metrics, since several important connection efficiency metrics can be considered as particular examples of it (e.g., the Harary index $\mathcal{H}(G)$ and the utility of communication $\mathcal{U}(G)$). The main objective of the optimization problem in question is to find the largest subgraph with a given level $\gamma \in (0, 1)$ of communication efficiency. We prove that the decision version of the problem is NP-complete for rational values of $\gamma \in [1/2, 1)$. Then we develop MIP-formulations, enhancements and an exact iterative algorithm. Finally, we discuss relations of a new clique relaxation model to other known clique relaxation models.

A New Clique Relaxation Model with Small-World Properties
Jongeun Kim, University of Florida

Abstract: Several clique relaxation models have been developed to detect a robust cluster from the networks. Most models consider one structural measure such as diameter, edge density and clustering coefficient However, this limited consideration sometimes produces a vulnerable cluster and we analyze the weakness of existing clique relaxation models by worst-case analysis. We propose a new clique relaxation model considering multiple measures, the so-called "small-world properties". The model is formulated as a mixed-integer program. Moreover, a heuristic algorithm that performs well on the considered problem instances is proposed for practical purposes.

Network Optimization on Materials Graph. Estimates For The Independent Union of Cliques Problem
Eugene Lykhovyd, Texas A&M University

Abstract: The first part includes the network analyzes to the Material graph. We know that a lot of real-world objects can be represented as a graph, such as social or financial systems, to explore interesting

relations. Recently there was an attempt to represent materials as a network too. The so called *Material Cartogram* is a graph with materials as vertices and edges with the relations between materials. Those relations are based on the band structure and one can define a similarity function to evaluate how distinct or, on the other hand, congruent two materials are. The objects of interest here are basic network properties based on the cut-offs for the similarity. The second part will talk about the problem named *independent union of cliques*. If you have a simple, undirected graph, the problem is to find the maximum subset of vertices, which form a vertex-disjoint union of cliques (which are complete graphs, i.e. those containing all possible edges). This problem is *NP*-hard and we propose the estimates for the solution based on Shor's dual estimates which is the method dual to SDP relaxation. It is know that the problem of interest can be formulated as the independent set on 3-uniform hypergraphs, and SDP relaxation worked well for independent set in graphs (known as Lovász estimate or number). So one can expect it to work well on hypergraphs too. However, the straightforward approach will generate a lot of constraints and slow down the calculation. We propose a little different quadratic formulation to reduce the problem size, but maintaining the small gap.

TruthCore: Non-parametric Estimation of Truth From A Collection of Authoritative Sources
Tathagata Mukherjee, Florida State University

Abstract: The World Wide Web has become the most important source of information for all of us today.Most often than not we access this information through the use of search engines, which collect and present information from several authoritative sources. The sources usually disagree about the information being sought making it difficult to decide on the correct information. In this paper we consider the problem of finding the most reliable source from amongst a collection of authoritative sources. We present a simple algorithm after formulating the problem as an outlier removal problem. We call our algorithm TruthCore as it attempts to find the most reliable source by mapping the sources into the vertices of a complete graph. The most reliable source is determined by finding the vertex that lies at the core of this graph. We report experiments on several real world datasets. We also used TruthCore for automatically correcting errors in OpenLibrary book data.

1:00-2:30 Session C2 (Room 117)

Monocular Camera Depth Filtering using Particle Filters
Zachary Bell, University of Florida

Abstract: Given the unreliability of global positioning systems (GPS), especially for aerial and ground vehicles operating in contested or denied environments, the need for position estimation through other means is essential. In addition to self localization, it is desirable to perform 3D localization of targets. Advances in computing and image sensors have allowed for image based localization techniques to be used as feasible solutions to these problems. Existing techniques, such as essential and homography decomposition, are capable of recovering translation up to a scale factor and rotation between two views with a calibrated camera. This scale factor in translation comes from image sensors inability to capture depth to objects in a scene motivating the development of techniques that recover this missing information. In this work, an image-based observer is developed that performs 3D localization of objects in a scene using particle filters. This technique may be incorporated into applications such as visual odometry, target tracking, or vision based simultaneous localization and mapping. Experimental results are presented in a scenario where a camera tracks multiple fixed objects and the position between views of the objects is assumed measureable.

Imitating Fixed-wing Aircraft Fight Characteristics for use in Multirotor Surrogate
Christian Harris, University of Florida

Abstract: Given the high cost of performing full-scale testing in aerospace applications and the limitations of simulation software, it is desirable to develop inexpensive platforms capable of testing guidance, navigation, and control (GNC) theory. When testing GNC theory, researchers have traditionally used multirotors as a means of imitating fixed-wing aircrafts, while remaining in a controlled indoor environment. The drawback to this method is that the vehicle dynamics of the multirotor does not sufficiently represent that of the fixed wing aircraft and can influence the nature of the theory being tested. This work seeks to use multirotors as a surrogate for fixed-wing aircrafts by focusing on the guidance laws to better represent the dynamics of a fixed-wing aircraft. This algorithm is used to test a guidance algorithm and controller that uses a gimbaled camera to guide the fixed-wing aircraft to maintain line of sight of a single ground target.

Experimental Validation for Visual Servo Control of an Unmanned Ground Vehicle via a Moving Airborne Monocular Camera
Hsi-Yuan Chen, University of Florida

Abstract: An experimental validation of a daisy-chaining based visual servo controller is performed. Specifically, the cooperative daisy-chaining controller is implemented with the objective to regulate an unmanned ground vehicle (UGV) to a desired pose utilizing the feedback from a moving airborne monocular camera system. In contrast to typical camera configurations used for visual servo control problems, the daisy-chaining controller is developed using a moving on-board camera viewing a moving target. Multi-view photogrammetric methods are used to develop relationships between different camera frames and UGV coordinate systems. In this experiment, a remote laptop, a Turtlebot (mobile robot),three stationary reference objects (e.g., buildings), and an AR.Drone (quadrotor) with a 720p resolution camera are used. The images received from the camera on-board AR.Drone are processed using OpenCV to extract and track features. The tracked feature points are fed into the controller implemented in MATLAB. The velocity commands generated from the asymptotically stable controller are broadcasted to the Turtlebot via Robotic Operating System (ROS) to achieve regulation to a desired pose. For performance verification, data collected from motion capture system is used as ground truth and plotted against the desired pose.

2:30 Concluding Remarks