Nonlinear Dynamics of Fluid and Structural Systems

Earl Dowell
Duke University

Fluid and structural systems and their possible interaction have a rich array of behavior being susceptible to instabilities and thus the generation of limit cycle oscillations and on occasion chaotic response. in this talk we will touch on several example including solar sails, high performance aircraft and aerodynamic decelerators from space into planetary atmospheres. Much of the talk will be devoted to the large and small scale oscillations that may appear in fluid flows and thus excite structural motion. The large scale motions include buffet in aircraft and non-synchronous vibration in jet engines, the classic case being the Von Karman vortex street. The small scale motions have as their most well known example the transition from laminar to turbulent flow. In all of the above cases a combination of theory, computation and experiment is used to understand the nonlinear dynamics of such systems.

Scale-reduction Techniques for Optimization Problems in Networks

Sergiy Butenko
Texas A&M University

Many large-scale networks arising in practice are characterized by special structural properties. This talk will discuss how these properties can be exploited in developing exact algorithms for solving NP-hard optimization problems on real-life networks.

Node Interdiction in Coupled Interdependent Networks with Cascading Failures

Vladimir Boginski
University of Florida

We consider node interdiction problems in two-layer interdependent networks with cascading node failures that can be caused by two common types of interdependence ("one-to-many" and "many-to-one"). Previous studies on interdependent networks mainly addressed the issues of cascading failures from a numerical simulations perspective, whereas this work proposes a rigorous optimization-based approach for identifying an optimal subset of nodes, whose deletion would effectively disable both network layers through cascading failure mechanisms. We discuss computational complexity issues, mathematical programming formulations, related theoretical results, and possible extensions of the considered problems. We also present computational experiments that illustrate interesting properties of interdependent networks with different types of interdependence.

Multi-Purpose Guidance

James Cloutier
Air Force Research Lab

A multi-purpose guidance structure is developed which contains reference signals to which the vehicle's inertial position and velocity are slued. The guidance structure is the optimal solution of an infinite-horizon, time-invariant, linear-quadratic regulator with servomechanism action. The structure represents an infinite family of guidance laws since there are an infinite number of ways of selecting the position and velocity reference signals. Using the geometry of the guidance problem at hand, proper reference signals can be derived to make the guidance law perform as desired. Numerous air-to-surface guidance laws and an all-aspect proportional navigation-like guidance law have been produced. Against both fixed and moving targets, the algorithms are capable of guiding the vehicle in the execution of (1) satisfaction of pre-specified terminal flight path angles, (2) a stealthy low approach to the target followed by a pop-up maneuver, (3) obstacle avoidance maneuvers, (4) a strictly homing mode, and (5) ingress to a search area followed by circular search, circular surveillance, and attack of multiple targets The guidance laws are evaluated via a three-degrees-of-freedom simulation and results are presented. It should be noted, however, that almost all of the guidance laws developed have been evaluated in various six-degrees-of-freedom simulations and have produced excellent results.

Optimal Control

Quang Lam
Air Force Research Lab

Robust Adaptive Control in the Presence of Unmodeled Dynamics

Heather Hussain
MIT

Robust adaptive control of scalar plants in the presence of unmodeled dynamics is established and demonstrated using the roll subsidence mode of the lateral-directional dynamics of an aircraft in the presence of actuator dynamics. It is shown that implementation of a projection algorithm with standard adaptive control of a scalar plant ensures global boundedness of the overall adaptive system for a class of unmodeled dynamics.

Higher Order Sliding Mode Control of 6DOF Hypersonic Missile during Terminal Approach using an Adaptive Observer

Stephen Phillips
The University of Alabama in Huntsville

The problem of terminal phase control of a six degree of freedom hypersonic missile is considered and addressed using a continuous higher order sliding mode controller. The scramjet engine of the hypersonic missile is considered to be in a shutdown mode and therefore the available thrust for control is considered to be zero. Since the aerodynamic forces are dependent on effects from each control surface, the governing equations are studied. The forces are presented in matrix form which allows for the design of independent control laws for each control surface. The overall system is considered a disturbance for the purpose of controller design and is reconstructed by an adaptive disturbance observer. The proposed controller may be verified for the longitudinal case.

On Connectivity Constraints in Integer Programs

Austin Buchanan
Texas A&M University

Many large-scale networks arising in practice are characterized by special structural properties. This talk will discuss how these properties can be exploited in developing exact algorithms for solving NP-hard optimization problems on real-life networks.

Connected Subgraph Polytope via Lifting Procedure

Yiming Wang
Texas A&M University

We study the problem of describing the connected subgraph polytope for graphs. We show lifting is an important technique to generate facet-defining inequalities for the polytope but it is NP-hard to generate a facet-defining inequality via lifting in general graphs. On the other side, we show lifting procedure generates a facet-defining inequality in linear time when the graph is a forest and such procedure gives a full description of connected subgraph polytope. We also consider the graphs with small independent number and gives full description of connected subgraph polytope when independent number is 2.

The Maximum s-Stable Cluster problem

Chitra Balasubramaniam
Texas A&M University

We introduce and study the maximum s-stable cluster problem which, given a graph and a positive integer s, asks to find a largest induced subgraph such that the size of the maximum stable set in the subgraph is restricted to s. This problem has applications in social network analysis and areas using graph-based data mining. We show the NP-completeness of the decision version of the problem, present an integer programming formulation and provide a detailed polyhedral study to identify different classes of facets. Two different solution methods are presented with preliminary computational results.

Heuristic approaches for detecting robust cliques in graphs subject to uncertain edge failures

Oleksandra Yezerska
Texas A&M University

We develop and compare several heuristic approaches for detecting robust cliques in graphs subject to uncertain edge failures. A clique is robust if it satisfies certain risk requirements modeled using the CVaR concept. The proposed heuristics employ techniques borrowed from the well-known tabu search and GRASP metaheuristics.

On the Lagrangian duality of the maximum γ-quasi-clique problem

Zhuqi Miao
Oklahoma State University

Quasi-clique detection has been witnessed as a useful tool for detecting dense clusters in graph-based data mining, especially in error-prone data sets in which clique model is overly restrictive. The maximum γ-quasi-clique problem (MQCP) which detects a maximum γ-quasi-clique from a given graph, can be formulated as a $\{0, 1\}$-program with a linear objective function and a single quadratic constraint. This research studies the Lagrangian duality of MQCP based on the quadratically constrained formulation, and developed a cutting plane method that is capable to provide both good feasible solutions and tight Lagrangian upper bounds for MQCP.

Resilient Network Design via Spanning k-Cores

Juan Ma
Oklahoma State University

Given a non-negative integer k, a graph of minimum degree at least k is called a k-core. The concept of k-cores can be used to design resilient networks that preserve low diameter and high vertex-connectivity upon random graph component failures. This talk focuses on minimum spanning k-core problem under probabilistic edge failures using appropriate risk measures. We discuss polyhedral reformulations and algorithms to solve the problem.

A Robust Relative Estimation Framework for GPS-Denied Navigation

Daniel Koch
Brigham Young University

This work presents a relative estimation framework for increasing the robustness of GPS-denied navigation solutions for small multirotor vehicles to varied and dynamically changing environments. Primary goals include enabling seamless transitions between indoor and outdoor flight, as well as robustness for flight in changing environmental factors such as lighting conditions. The proposed framework should allow for the modular integration of multiple keyframe-based sensors and algorithms such as visual odometry and laser scan matching. The framework should also be able to detect and robustly handle sensor failures and degraded sensor performance to maintain good estimates in challenging conditions.

Comparison of Bayesian Search Algorithms

Drew Ellison
CU Boulder

Integrated surveillance and reconnaissance (ISAR) missions are an important application class for cooperative networks of unmanned aerial vehicles (UAVs), which must provide timely information about adversarial activities, environmental conditions, and friendly asset status to support coordinated dynamic decision-making. To improve the robustness and performance of such systems in urban environments, the AFRL Munitions Directorate seeks to develop formal online estimation and planning strategies for conducting probabilistic target search using MAVs (such as quadcopters) in urban indoor/outdoor environments. The current work being done explores the comparison of discretized space Bayesian search algorithms in realistic urban environments. The discretization of space, however, often scales poorly and is computationally expensive. This motivates the development of information-drive continuous planning techniques for quadcopters.

Distributed Solutions to the Dynamic Weapon Target Assignment Problem

Kyle Volle
Georgia Institute of Technology

The weapon-target assignment problem has been the subject of much research in the field of combinatorial optimization. A generalization of the classical assignment problem, it allows for multiple agents to be assigned to any given task. In particular, this work investigates the distributed, dynamic, weapon-target assignment problem where each agent makes decisions without the aid of a central planner and replan throughout the engagement as the situation changes. The assignment algorithm presented here uses a distributed game-theoretic approach where individual agents probabilistically switch to targets that improve the overall distribution. The algorithm leverages the fact that for large numbers of agents, each agent can only affect a small portion of the state space meaning that each agent?s decisions are largely independent so long as asynchronicity is maintained. As a result, a relatively straightforward local optimization approach converges exponentially to the global optimum. The relative priority of targets can be expressed as the desired probability of successful engagement of that target. A dynamic simulation of autonomous air-to-ground munitions is presented for testing and evaluation the proposed assignment algorithm. This simulation implements varying time-to-targets for each agent as well as a stochastic attrition model that represents unknown defensive capabilities on the part of the enemy. Results are compared to a naïve assignment approach in terms of overall system effectiveness.

Cooperative estimation for feature-based SLAM

Timothy Woodbury
Texas A&M University

In simultaneous localization and mapping, a vehicular agent creates a map of perceived landmarks in its environment while estimating its own position relative to said landmarks. In the current research, two agents operate in a purely planar workspace. The agents share landmark measurements to improve estimation accuracy. Sharing is effected by equipping each vehicle with sensors that measure the relative range and bearing to other agents. The preliminary results presented consider only the localization problem, in which landmarks are sensed but have a priori known locations. Each agent constructs an Extended Kalman Filter of its own position and translational velocity, and uses a nonlinear measurement model to incorporate landmark measurements made by itself and by the other agent. Estimation effectiveness is considered in Monte Carlo simulations. Two scenarios are considered; one in which landmark range and bearing is sensed, and one in which landmark bearings only are measured. Interagent measurements are available in both cases, and the performance of agents with and without measurement sharing is contrasted. Simulations are conducted at varying sensor variance levels and with varying numbers of features to gain insight into when this cooperative estimation scheme offers greatest benefits. All simulations consider two agents only; however, the architecture presented does not require the estimation of any additional states, and the only computational burden added by cooperation is a larger measurement vector. This architecture should be extensible to larger teams of agents, limited only by interagent communication bandwidth and relative agent sensing quality.

Hardware and Capability Build for an Autonomous Relative Navigation Framework

Gary Ellingson
Brigham Young University

In recent years researchers at Brigham Young University have been working on a relative navigation framework for autonomous aircraft. The framework and associated hardware platform have been a testbed for collaborative study of multiple associated researchers topics. The hardware platform consist of a multi-rotor aircraft carrying a autopilot for low-level attitude control and an Intel i7 computer running ROS for higher level functions. However, because of an unreliable and proprietary autopilot, testing of the higher level functions has been limited. The researcher has exchanged the proprietary autopilot for the open source solution allowing for more flexibility and control of the software used for low-level functions. Low level estimation and control have been integrated onto the autopilot and flown while receiving commands from an on-board computer. Testing of higher level navigation functions is now possible. Further, as the research matures, more of the relative navigation framework will be moved from the on-board computer to the autopilot allowing for more real-time execution.

Control of Nonlinear Aerospace Systems using Micro-Jet Actuators

Siddhartha Mehta
University of Florida

Store-Induced Limit Cycle Oscillations due to Nonlinear Wing-Store Attachment

Madhusudan Padmanabhan
Duke University

Fighter aircraft encounter aeroelastic Limit Cycle Oscillations (LCO) when carrying certain combinations of under-wing stores, leading to structural fatigue as well as pilot discomfort and loss of eff?ectiveness. The roles of various aerodynamic and structural non-linearities involved in the LCO are not well understood, and their numerical exploration via time marching is computationally expensive. In the absence of reliable prediction of critical parameters such as onset speed and response level, current practice is to restrict store carriage to a safe subset of the flight envelope. This work examines a possible cause for LCO, namely a structurally nonlinear (in stiff?ness and damping) wing-store attachment, without or with nonlinear aerodynamics. The wing-store attachment is modeled with a ?finite, adjustable stiff?ness that can accommodate the nonlinearity. Results are obtained by the computationally effi?cient Harmonic Balance (HB) method and compared against time marching solutions. For the case of nonlinear damping, an adaptation of the HB method for nonlinear sti?ness is used. Two systems are considered, namely a generic wing-with-store and the F-16 aircraft, respectively. Whereas the wing is modeled directly, the aircraft linear structural model is obtained from the Air Force Research Laboratory and modi?fied subsequently to include the wing-store nonlinearity.

Multi-Grid Analysis of High Order Synthetic Jet Actuators and LCO Simulations

Marco Sansone
ERAU

The current work investigates the use of Synthetic Jet Actuators (SJAs) in both low speed acoustic noise reduction, and Limit Cycle Oscillation (LCO) control. Both are analyzed with the Air Force FDL3DI code, which solves the full Navier-Stokes Equations.

Post processing of both cases is handled by the code JAFpp. Previously, this code was split into separate versions that have now been integrated together, along with the ability to function with multi-grid meshes. It is capable of extracting data from the FDL3DI solution files for the airfoil surface, Kirchhoff surfaces, and points above and below the trailing edge, and prints a time average flow file for the entire domain. In addition, it has been made more robust with automatic point selection for the trailing edge points and Kirchhoff surfaces that were previously inputted manually.

The ongoing noise reduction study continues the work of Cody Sewell on high fidelity simulations of the Joukowski symmetrical airfoil, with and without embedded SJAs. Current results from retesting his parameters roughly match the published results, but irregularities in the grid independence study point to instabilities that must be researched further. LCO simulations will be performed on the NACA0012 airfoil with 2 embedded SJAs, with updated modules written by Lap Nguyen. The control parameters governing the SJAs were written by Dr. William Mackunis.