Munitions Directorate Overview

Mikel Miller
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An overview of the Air Force Munitions Directorate.

Critical Nodes for Communication Efficiency and Related Problems in Graphs

Oleg Prokopyev
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In graph-theoretical models the decision-maker is often interested in evaluating the overall system's vulnerability and robustness properties with respect to node failures. One popular strategy, which is often applied for addressing this question, is based on the concept of critical nodes, defined as a subset of nodes whose removal maximally degrades the connectivity of the considered graph or, equivalently, maximally fragments the graph according to some pre-defined metric. The corresponding optimization problem is known as the Critical Node Detection problem (CNP). In this talk we first review some of the recent results in the area. Furthermore, we propose a new class of CNPs that consider communication efficiency of the graph, which is assumed to be a general distance-based metric (e.g., Harary index, characteristic path length, residual closeness) that depends on actual pairwise distances between nodes in the remaining graph rather than simply the fact whether nodes are connected or not, which is a typical assumption in standard CNP models. We discuss in details the developed solutions approaches and briefly overview the results of our computational experiments on real-life and synthetic networks. In particular, one important conclusion of our work is that vulnerability of real-life networks to targeted attacks can be significantly more pronounced than what can be estimated by using heuristic methods commonly used in the literature. Finally, we discuss some related implications of our work to distance-based clique relaxations, namely, s-clubs. This is a joint work with Alexander Veremyev and Eduardo Pasiliao.

New Integer Programming Based Approaches for Finding Maximum Quasi-Cliques and Dense Subgraphs

Alexander Veremyev
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Dense component discovery is one of the most important aspects of network analysis. In many real-life networked systems, dense regions may indicate high degrees of interactions, pairwise similarities, and may correspond to communities sharing some common properties. Naturally, from a graph theoretical perspective, dense components have small diameters and average pairwise distances. Moreover, they are usually robust in the sense that they remain connected even if many links become "broken,?? e.g., due to an attack or a failure. Dense components have been studied in many types of networks, including social, communication, internet, financial markets and biological systems. Identifying the maximum dense network clusters is typically an NP-hard problem. In this talk, we present a new integer programming (IP) based approach for finding largest dense components in graphs. Specifically, we first develop several new IP formulations and exact iterative algorithms for solving the maximum ?-quasi-clique problem, which seeks for the largest subgraph with edge density $\gamma \in (0, 1)$. We derive upper and lower bounds for LP relaxations of new formulations and demonstrate that our upper bounds are substantially tighter for sparse graphs (real-life networks are typically sparse) than the LP bounds obtained using other formulations available in the literature. Second, we show that the proposed methodology can be naturally generalized for the $f(k)$-dense subgraph problem, which seeks for the largest subgraph induced by k vertices with at least $f(k)$ edges. In particular, we discuss two well-known examples of such graph structures: $f(k) = k(k-1)/2 - s$ (s-defective clique) and $f(k) = k(k-s)/2$ (average s-plex). Finally, we illustrate performance of the proposed formulations and exact algorithms for various real-life and synthetic networks instances by solving instances with up to 10000 vertices. The talk is based on a joint work with Oleg Prokopyev, Sergiy Butenko, and Eduardo Pasiliao.

Casting Visual Search Problems as Optimization Problems to Solve in Real Time

Nicholas Gans
University of Texas at Dallas

Information Fusion in Human-Robot Collaboration using Neural Network Representation

Ashwin Dani
University of Connecticut

Simultaneous Target Estimation and Path Planning in Urban Environments

Michael McCourt
University of Florida

Target location estimation and path planning are each crucial components of target interception. However, there are limitations to the achievable performance when considering these two problems separately. This is especially true when considering nonlinear motion models with non-Gaussian state uncertainty. This presentation explores a framework for simultaneous estimation and path planning in real time. The target state estimation makes use of the particle filter framework for recursive Bayesian estimation. Path planning is achieved using rapidly-exploring random trees. The path to traverse is chosen based on a recursive optimization problem that balances the goals of reducing uncertainty in the environment and intercepting the target in minimum time. Preliminary simulations have been completed that provide a baseline performance for this framework.

Computational Challenges in Assured Distributed Seeker-Sensor Fusion

Piyush Kumar
CompGeom Inc.
Florida State University

In this talk, we present the challenges faced by drone designers when using wide filed of view cameras to do precise location in GPS Free or noisy GPS environments. We will explore multiple proposed solutions to this problem.

Under adverse networking conditions, where noise in communication is an issue, we also look at estimating the noise level in the communicated bits. This is a precursor to designing assured communication algorithms that can smoothly communicate over lower bandwidth caused by noise. Our location computation proposal degrades gracefully as the bandwidth gets limited or the communication breaks.

A stochastic PDE-constrained optimization approach to active control of multifunctional composite structures

Pavlo Krokhmal
University of Iowa

A new two-stage stochastic partial differential equation (PDE)-constrained optimization methodology is developed for the active vibration control of structures in the presence of uncertainties in mechanical loads. The methodology relies on the two-stage stochastic optimization formulation with an embedded first-order black-box PDE-constrained optimization procedure. The PDE-constrained optimization procedure utilizes a first-order active-set algorithm with a conjugate gradient method. The objective function is determined through solution of the governing PDEs and its gradient is computed using automatic differentiation with hyper-dual numbers. The developed optimization methodology is applied to the problem of post-impact vibration control (via applied electromagnetic field) of an electrically conductive carbon fiber reinforced composite plate subjected to an uncertain, or stochastic, impact load. The corresponding governing PDEs consist of a nonlinear coupled system of equations of motion and Maxwell's equations. The conducted computational study shows that the obtained two-stage optimization solution allows for a significant suppression of vibrations caused by the randomized impact load in all impact load scenarios. Also, the effectiveness of the developed methodology is illustrated in the case of a deterministic impact load, where the two-stage strategy enables one to practically eliminate post-impact vibrations.

Accelerated methods for large-scale compressive sensing and machine learning problem

Yuyuan Ouyang
University of Florida

We present accelerated first-order methods for solving a class of convex optimization problems that has wide applications in compressive sensing and machine learning. Since only first-order information of the objective function is used, the proposed methods possess cheaper iteration costs and are suitable for many large-scale optimization problems. By incorporating Nesterov's multi-step acceleration scheme, we prove that the proposed methods have improved iteration complexity in terms of the Lipschitz constant of the smooth component in the objective function. Preliminary experimental results are presented to demonstrate the effectiveness of the proposed methods.

A Switched Systems Approach to Vision-Based Localization of a Target with Intermittent Measurements

Anup Parikh
University of Florida

Switched theory is used to analyze the stability of vision-based observers for 3D localization of features in a scene. Filters that are exponentially stable under persistent observability may have unbounded error growth under intermittent sensing loss, even while providing seemingly accurate state estimates. Therefore, trust conditions are developed based on an average dwell time criteria to guarantee state error convergence with a known decay rate. In cases where observability is controllable, these conditions relax path constraints for visual servoing applications. The conditions are developed in a general form, applicable to any exponentially stable observer, and utilize feature motion knowledge to maximize the allowable time spent in stabilizable, but unobservable, periods.

Target Search and Acquisition by UAVs and Unattended Ground Sensors in Urban Environments

Pablo Ramirez
University of Texas at Dallas

We are concerned with the search and acquisition of a moving target in an urban environment, using mobile sensor platforms and stationary sensors. We assume prior knowledge of the environment and a target with no evasion tactics. A particle filter is used to estimate the target state, allowing us to remove assumptions like linear dynamics of the target or a Gaussian distribution of its states. We explore the use of Unmanned Aerial Vehicles (UAVs) as the mobile sensor platforms. Depending on the type of aircraft selected, it can be possible to obtain data at different resolutions in both the spatial and temporal domains. The use of sensor carrying mobile robots such as UAVs is not the only information gathering strategy to cover. In addition, we will incorporate stationary Unattended Ground Sensors (UGS) which may not provide information accurate enough to guarantee detection beyond a certain threshold, but which will aid in the location of the target. The range to which these sensors can communicate is limited, giving rise to delayed measurements. Due to this fact, we are developing techniques to incorporate time-delayed information into our search and estimation scheme. The search and tracking task can be cast as an optimization problem, in which the cost function contains terms reflecting the energy expenditure of the sensor platforms and the amount of uncertainty about the target at a given time. By minimizing this function the target can be located and tracked while using every information gathering resource available at once.

Decentralized Event-Triggered Based Containment Control for a Network System

Teng-Hu Cheng
University of Florida

A decentralized event-triggered control scheme for containment control problem is developed. The control strategy seeks to reduce communication over the network thereby reducing energy consumption and reduce a potential of communication congestion while still achieving the control objective. To this end, an estimate-based controller that requires only intermittent communications with its neighboring agents is developed: instances requiring communication are determined by a decentralized trigger function. The decentralized trigger function is designed so that each agent requires only local information to detect the next event-time for communication. Since the trigger function produces switched dynamics, analysis is provided to show that Zeno execution is avoided. A Lyapunov-based convergence analysis is also provided to ensure the developed strategy yields asymptotic convergence, which is also supported by simulation results.

Design of a guidance controller using network topology

Clay Robertson
Auburn University

This presentation aims to address a decentralized control problem through the use of an agreement, or consensus, protocol. Given a connected network of heterogeneous unmanned aerial vehicles, a guidance controller is designed to react to the changing internal consensus dynamics of the network. This project utilizes the internal consensus dynamics in an effort to design a guidance controller that flows between a leader-follower and virtual structure formation, viewing the two formation structures as part of a continuum by manipulating the guidance controller?s dependence on the internal network dynamics.

An analysis of directed and undirected graphs and their effect on the consensus dynamics is presented. Looking at chain and branched networks, the time response and controllability of a network using a single node for the exogenous input provide metrics to develop a hierarchy of leadership within the network. With a predetermine network structure set by the selection of a leader for the network dynamics, the effect of leadership placement within the physical dynamics of the flight formation are analyzed as well for the two formation types. Lastly, the effects of a human input to the leadership node is researched to determine the form of feedback the user needs to effectively pilot the formation as well as the reaction of the formation to a exogenous input.

Frontier Based Exploration with the use of Navigation Function

Carlos Caballero
University of Florida

In this investigation, a frontier exploration based approach is presented that uses a navigation function for collision avoidance. In an effort to maximize exploration area, two possible probability based methods are described which utilize knowledge of a compiled occupancy grid.

Rough-Map Merging by Clustering Obstacles

Jinyoung Park
Auburn University

In mapping a ground area by aerial vehicles, completeness the map depends on the performance of the vehicle?s obstacle-detection sensors. The sensor transmits a signal to the ground and receives a reflected signal, thereby recognizing the obstacles. If the sensor has low frequency or the vehicle moves too fast, the sensor will miss some portions of obstacles. This study researches map merging of two agents that have such sensing limitations.

Since the obstacles in maps from the agents have missing portions, even the same obstacle in both maps can have different shapes. This makes finding overlapping coordinates to merge the maps an issue. However, if several neighboring obstacles are considered as a cluster in both maps, the shape of the clusters will have similarities. This algorithm finds the most similar clusters and merges the maps by overlapping coordinates. Because this merging is based on probability, the obstacles in the merged map may be offset from the actual arrangement of the obstacles. However, this study proposes an approach to the rough-map merging problem.

Path Planning for Multiple Observer, Multiple Target Vision-Based Tracking Applications with Loss-of-Sight Considerations

Ryan Licitra
University of Florida

In many applications, it is desirable for one or more agents to possess the ability to visually track multiple targets, and maintain minimal target-tracking position estimation error when there are loss-of-sight occurrences. When more than one agent is involved, it is imperative that the agents work together so that these loss-of sight situations are minimized, and overall target tracking in a convex, finite search area can be achieved. This work proposes a decentralized controller that will adjust the waypoint locations of each observing agent?s path in real time, given known information about the environment acquired by every observing agent, as well as their current path waypoint locations. Each observing agent must be able to independently run the path planning algorithm, gather data about the environment using a bottom-mounted camera, and share its interpretations with the remaining observing agents. In addition to updating its current path, each observing agent will also implement a controller to influence how it will travel along its path. This will include how fast to traverse along its path to the next waypoint, as well as whether or not to loiter at times or reposition itself to improve the efficacy of its field of view. These control laws will be influenced by a virtual area of interest sensory function cast over the ground plane which will vary with time based on current environment information, but will appear identical to all observers at any given time. This area of interest can be modeled as truncated Gaussian distributions centered at the most recently known location (or best prediction of current location) of currently and previously tracked targets. The magnitudes and truncation parameters of these distributions at a given time will be calculated using a profit/reward numeric system based on calculated "dwell on" and "dwell off" times. These dwell times will define the minimum time a target must be in an observer?s field of view (?dwell on?) and maximum time it may remain out of an observer?s field of view (?dwell off?) in order to guarantee target position tracking error convergence. Each waypoint will be drawn to the centroid of its Voronoi region, with the area of interest sensory function acting as the density function.

An Integer Programming Framework for Detecting Sybil Nodes in Online Social Networks

Chrysafis Vogiatzis
University of Florida

As online social networks become bigger and more widespread, they also become more prone to Sybil node attacks. In its most basic form, a perpetrator creates multiple identities and tries to form bonds with "honest" users in order to disperse information, affect elections, and intercept messages. We formulate the problem as a Rayleigh ratio problem, and derive the complexity of detecting cohesive and highly associated subgraphs with sparse cuts to the rest of the network. We conclude by proposing different approaches to tackling the problem, and showing some preliminary computational results.

Detecting Critical Vertex Structures on Graphs: A Mathematical Programming Approach

Jose Walteros
University of Florida

In this study we consider the problem of detecting a collection of critical vertex structures of a graph, subject to different budgetary constraints, whose deletion optimally deteriorates the graph's connectivity and cohesiveness. The principal objective of the proposed approach is to generalize other models existing in the literature whose aim is restricted to removing individual and unrelated vertices. We focus our attention on the cases where the vertex structures are cliques or stars, albeit the proposed technique es general enough to be easily extended for detecting other critical structures. We first introduce a general mathematical formulation as a mixed integer linear program, which, depending on the kind of vertex structures, may have an exponentially large number of variables and constraints. To solve this potentially large model, we develop a branch-price-and-cut framework and use it for solving the particular cases of the cliques and stars. We provide computational complexity results for both of such cases and develop additional preprocessing algorithms to speed up the column generation stage of the algorithm. Finally, we test the quality of our approach by solving a collection of several real-life and randomly generated instances with various configurations analyzing the benefits of the proposed model as well as some possible further enhancements.

Sequential network interdiction with incomplete information

Juan Borrero
University of Pittsburgh

We study sequential interdiction of evaders on a network when the interdictor has partial initial information about the network structure and costs. In each period, the interdictor removes up to k arcs from the network, after which an evader travels along a shortest path. By observing the evaders' actions, the interdictor learns about the network and adjusts its actions accordingly. We analyze a class of policies that remove a set of k-most vital arcs of the observed network, and assess its optimality. A salient feature of our work is that the feedback each period is deterministic and adversarial.

This is a joint work with Dr. Denis Saure (Universidad de Chile) and Dr. Oleg Prokopyev (University of Pittsburgh).