Arctic Domain Awareness Center (ADAC)

Developing Unmanned Maritime Vehicle Cooperation to improve Artic Domain Awareness

Abstract: The principal goal of this 8–week summer research project, conducted as a part of the 8th annual Summer Research Institute hosted by the Maritime Security Center at the Stevens Institute of Technology in Hoboken, NJ, was to transform the body of an unmanned surface vehicle (USV), specifically the Wave Adaptive Modular Vessel, into an autonomous mothership for a remotely operated vehicle (ROV), the VideoRay Pro 4. The produced concept includes a method for the USV to autonomously deploy and retract the ROV by its data transmission tether for underwater inspection at an objective area. In addition, this research team, composed of six undergraduate engineering and other technical disciplines students, addressed determining a method to permanently mounting an acoustic Doppler Velocity Log (DVL) to the ROV without significantly hindering the ROV's underwater performance. Lastly, the team was tasked with understanding how the DVL records data and how that data could be utilized for the integrated USV and ROV to maintain station-keeping ability while conducting autonomous operations. Working collaboratively under Principal Investigator, Dr. Brendan Englot, the team was able to design and fabricate a mounting apparatus for the DVL to attach to the ROV, as well as produce concept designs for how the ROV may be employed with the USV to satisfy the vehicle's desired function as a mothership. An individual effort was continued at the Arctic Domain Awareness Center, hosted by the University of Alaska Anchorage, to apply these solutions to Arctic maritime domain awareness. Concepts included methods to apply the integrated system to conduct bathymetric mapping, subsea inspections, and a variety of unmanned safety and security missions to be pursued by ADAC's principal customer, the U.S. Coast Guard.

Student(s): Kyle A. Alvarado, Victoria Kapp, Max Panoff, Anthony Orrico, Mathew Green, and James Fredericks, Undergraduate Student Research

Advisor(s): Dr. Brendan Englot, Stevens Institute of Technology

Development of ICECON, a Ship-Specific Forecasting Tool for The Great Lakes

Abstract: A need exists for a ship-specific ice forecasting system for the Great Lakes. The ICECON project seeks to address this. The current ICECON system is based on a National Ice Center algorithm that employs air temperature, ice concentration, ice thickness, wind speed and direction, and ice type. These factors all contain separate sub-categories; these sub-categories are assigned their own weights. The proposed improvements include the addition of vessel classes and parameters, ice recovery factors, and changes in internal icepack pressure. The ICECON project has several winters' worth of data collected by the United States Coast Guard (USCG) 9th District icebreaker captains. This data will be used for calibrating ICECON. The proposed input data for ICECON is forecasted ice data from the Great Lakes Coastal Forecast System (GLCFS), which is maintained by the Great Lakes Environmental Research Laboratory (GLERL). A Monte Carlo algorithm has been written and used to probabilistically assess the current state of ICECON, and will be used to determine the correct weights for new additions to ICECON. Although ICECON is a project for freshwater ice in the Great Lakes, it responds to ADAC's mission by providing a solid framework for future Arctic ship-specific sea ice forecasting

tools. The principles that apply to ICECON could easily apply to any future ship-specific sea ice forecasting models. The ADAC mission is also met through supporting the USCG to meet their mission in the Great Lakes region by increasing ice awareness for commercial traffic and first responders such as USCG icebreakers.

Student(s): Seth Campbell, Graduate Student Research

Advisor(s): Dr. Tom Ravens, University of Alaska Anchorage and Dr. Andrew Mahoney, University of Alaska Fairbanks

The Benefits and Potential Applications of Sea Ice and Weather Modeling Data in Local Search and Rescue (SAR) Operations in the Arctic

Abstract: This research investigates the potential use and application of radar, satellite, and other tracking data for sea ice and weather in maritime-related Search and Research operations in the Arctic. Specifically, this research looks into how sea ice and weather modeling data can help support emergency responders by deep-diving into a recent case study where modeling data from the University of Alaska Fairbanks and other research institutions was used to help support the local SAR of a lost small vessel due into Utqiaġvik (formerly, Barrow), Alaska in July 2017. This research investigates not only the type of data that was used to help support the vessel rescue, but also the implications for future use and uptake of modeling data in local SAR operations in Utqiaġvik. Given that local SAR operators are predominantly the first responders to maritime emergencies in the North Slope of Alaska, interviews with relevant stakeholders were conducted to understand SAR data needs as well as to identify existing data sources that can be shared or modified to help meet those needs. Data needs in this study are defined as those related to emergency response but more importantly, hazard planning. This study feeds into the Arctic Domain Awareness Center (ADAC) funded project - *Developing sea ice and weather forecasting tools to improve situational awareness and crisis response in the Arctic* - which seeks to create a prototype sea ice and weather forecasting module for hazard planning in Utqiaġvik.

Student(s): Dina Abdel-Fattah, Doctoral Student Research

Advisor(s): Dr. Nathan Kettle, University of Alaska Fairbanks

Remote Autonomous Sensor Networks: A Study in Redundancy and Life-Cycle Costs

Abstract: The remote nature of the United States and Canadian border and its diverse landscapes have made monitoring human movement over much of the area difficult using conventional techniques, especially on an as-needed-basis. In this study, the proposed solution aims to address that need by evaluating an autonomous sensor network's suitability in a selected environment while minimizing the environmental impact. This solution can function as a stand-alone monitoring network or provide additional spatial and temporal resolution to existing monitoring networks.

A prototype sensor was designed and constructed by the University of Alaska (but was not field tested). Movement is detected by identification of an acoustic disturbance by a microphone (acoustic detector) and/or identifying modulation in the radio frequency signal between sensor locations. A model with Boolean criteria was designed which uses geospatial datasets to estimate sensor survivability in a given environment given the proposed design. Additionally, the SPreAD model calculated the acoustic detection distance for the sensors and the radio frequency transmission distances were not calculated. The

results detail the expected number of sensors necessary to ensure complete coverage of an area of interest. Furthermore, this approach allows the integration of redundancy factors to ensure that if a sensor is non-responsive there will be a defined impact on the detection and communication architecture.
The environmental impact of the sensor was evaluated by performing a modified Life Cycle Assessment (LCA) and evaluating if the components meet RCRA guidelines to ensure that toxic materials are not used. The methodology analyzes a sensor design, identifying components that can be modified to reduce the overall environmental impact of the sensor without influencing performance. The total environmental cost for the network is calculated by taking the LCA result and multiplying it by the estimated number of sensors necessary to ensure coverage of an area of interest.

Student(s): Mathew Ahlrichs, Graduate Student Research
Advisor(s): Dr. Aaron Dodson, University of Alaska Anchorage

Oil Beneath Arctic Sea Ice - Predicting Storage Capacity as a Means to Better Anticipate Oil Slick Spreading

Abstract: In planning for response operations to possible Arctic oil spills, emergency responders, such as the U.S. Coast Guard, will need to be able to estimate the potential quantity of oil stored beneath a given area of Arctic sea ice. The presence of ice complicates the clean-up process as Arctic sea ice is not flat under the water, rather it presents non-geometric, unpredictable protrusions into the water column. If the current does not swiftly move the oil away from the ice, the oil becomes trapped in these inverted caverns until completely encapsulated by the ice. Oil may stay locked away until spring thaw or may migrate upward through brine channels until it reaches the surface, affecting local wildlife and inhabitants. This study establishes a preliminary relationship between ice subsurface storage capacity and current surface conditions. Historical reports on Arctic ice conditions and concentrations were obtained from the National Oceanographic and Atmospheric Administration (NOAA). Data on the ice subsurface was collected by Shell using upward looking sonar, and their data was published by the North Slope Science Initiative. Surface and subsurface information was gathered for both the Chukchi and Beaufort Seas, located off the northern coast of Alaska. By merging this data, the project team was able to develop estimations of oil storage capacity on a low, middle, and high spectrum. First responders will now have access to a more comprehensive picture of the volume of oil hidden beneath the ice given known ice surface conditions in the event of a spill.

Student(s): Kelsey Frazier, Undergraduate Student Research
Advisor(s): Dr. Tom Ravens, University of Alaska Anchorage

Borders, Trade and Immigration Institute (BTI)

The Modified Online Delphi Process Software

Abstract: The Delphi method is a forecasting technique in which experts undergo successive rounds of anonymous voting in order to reach an approximate consensus on an issue. While the classic Delphi method, originating in the 1950's, required the physical presence of experts, modern technology allows for a virtual meeting which may be more convenient. Using the Google's G Suite, we created a web application which allows a research group to

execute a study using the Delphi method in which subject matter experts may participate remotely. The only required technology is a computer or smartphone with an internet browser. We designed the software with the particular application in mind of investigating deterrence and detection rates for populations illegally crossing the border. In particular, we augmented the classic Delphi method to include a preliminary discussion phase in which relevant demographics and time frames are determined and entered into the application. After receiving this input, the software generates a questionnaire to send to the experts. Once the experts have undergone a number of voting rounds, the software is able to weight the input of experts, based on their accuracy in projecting certain observable data, to generate improved estimates of variables that cannot be directly observed.

Student(s): Katie McKeon, Graduate Student Research

Advisor(s): Dr. Dennis Egan, Rutgers University

The Homeland Security Symposium Series at the University of Texas at El Paso, a project of the Borders, Trade, and Immigration (BTI) Institute at the University of Houston

Abstract: The aim of this program is to assist in maturing and strengthening the homeland security enterprise, as outlined in the 2014-2018 DHS Strategic Plan and 2014 Quadrennial Homeland Security Review. In particular, the goal of enhancing the DHS Workforce is supported by the program. The Homeland Security Symposium Series addresses educational and supplemental training needs identified by DHS and other homeland security enterprise stakeholders. The University of Texas at El Paso (UTEP) developed a symposium series on topical issues related to border security and legitimate trade and travel. The nature of the project allows other topical themes to emerge as stakeholders dictate. Symposium series topics and content are driven by the needs of stakeholders within the homeland security enterprise. The symposium series utilizes subject matter experts contracted by UTEP. Exit surveys are utilized and play a vital role in the development of future symposia events by seeking the participants' interest in both expanding the content of the symposia they attended or providing the opportunity to suggest other topical interests. UTEP conducts an exit survey after each event to review both positive and negative feedback regarding symposium content, instructors, facilities, and equipment. This information allows UTEP to evaluate itself and implement changes to improve the overall quality of the homeland security symposium series. Goals: (1) Disseminating research findings, data, and results from relevant research through face-to-face and online modalities; (2) providing training and education to meet the needs of DHS component agencies, local law enforcement, and other homeland security stakeholders. Intended Outcome: The intent of the project is to advance or impact the homeland security enterprise workforce capabilities by enhancing the knowledge, skills, and abilities of practitioners.

Student(s): Victor Reyes, Undergraduate Student Research

Advisor(s): Dr. Victor Manjarrez, University of Texas – El Paso

The Center for Awareness and Localization of Explosives Related Threats (ALERT)

Analysis of Synthesized Erythritol Tetranitrate (ENT) for Attribution

Abstract: Erythritol tetranitrate (ETN) is a low melting nitrate ester that has garnered attention for its possible use as a homemade explosive due to its ease of manufacture from readily available materials. This has especially grown as the precursor sugar, erythritol, is now nearly ubiquitous and widely available in large amounts. For these reasons, a large study was undertaken to determine if there were any defining characteristics that could differentiate between different batches of product ETN. Over 50 batches of ETN were synthesized via two routes, mixed acid and nitrate salt methods. Standard synthesis protocols were varied, including changing precursor materials, reaction conditions, and post-synthesis workup schemes. The synthesized ETN was subjected to numerous spectroscopic and spectrometric techniques, including infrared and Raman spectroscopies, as well as liquid chromatography-mass spectrometry (LC-MS), inductively coupled plasma-mass spectrometry (ICP-MS) and isotope ratio mass spectrometry (IRMS).

Student(s): Lindsay McLennan, Taylor Busby, Alex Yevdokimov, James Smith, Karlijn Bezemer, Lara van Duin, Jan Dalmolen, Chris-Jan Kuijpers, Mattijs Koeberg, Jos van den Elshout, Antoine van der Heijden, Peter Schoemakers, and Arian van Asten, Graduate Student Research

Advisor(s): Dr. Jimmie Oxley and Dr. James Smith, University of Rhode Island

Compressive Antennas for High-Sensing Capacity Imaging

Abstract: This poster presents the design and fabrication of a Compressive Reflector Antenna (CRA) and three feeding elements: a conical horn antenna, a compressive horn antenna, and a perturbed cavity. These designs are for the purpose of developing a high-sensing capacity millimeter wave imaging system. Millimeter wave systems are used for several near-field imaging applications such as security screening, non-destructive testing, autonomous driving, and biotechnology. Much of the recent development in this area has been in Synthetic Aperture Radar systems which have demonstrated high resolution and fine imaging performance. However, they usually suffer from complex hardware architecture and elevated cost. Compressive sensing systems can alleviate these issues by increasing sensing capacity, improving image reconstruction, reducing the number of measurements, and reducing the hardware complexity and cost. A CRA is a doubly-curved offset parabolic reflector antenna which has the capability to create pseudo-random spatial and spectral codes in the near- and far-field of the antenna, making it a good candidate for high-sensing-capacity imaging applications. This CRA is designed with perfect electric conductor (PEC) scatters on the face of the antenna. The CRA and feeding antennas are fabricated using a 3D printer and conductive silver spray, reducing the fabrication costs compared to traditional techniques. The performance of the CRA is evaluated by measuring the near-field of the antenna and calculating its Singular Value (SV) distribution and sensing capacity. For this purpose, the reflector is fed with each of the three aforementioned antenna elements separately: a conical horn antenna, a compressive horn antenna, and a perturbed cavity. From these tests, it is found that the perturbed cavity provides more randomness in the radiated fields (spatial codes) than the other two feeding elements, showing an improved SV distribution. The sensing capacity of the CRA system, which is defined as the maximum amount of information that can be transferred, is found to be best

when using the conical horn antenna. This is because the reduced spill-over of the conical horn antenna leads to a better signal to noise ratio. However, the tests demonstrate that all three elements provide significant spatial coding.

Student(s): Katherine Graham, Ali Molaei, Luis Tirado, Ashkan Ghanbarzadeh Dagheyan, Anthony Bisulco, Juan Heredia-Juesas, Chang Liu, Joseph Von Holten, Weite Zhang, Alexander Zhu, and Diego Cachay, Undergraduate Student Research

Advisor(s): Dr. Jose Martinez—Lorenzo, Northeastern University

Millimeter-Wave Multistatic 3D Personnel Screening System for Explosives-Related Threats

Abstract: This poster presents experimental results of a novel multistatic millimeter-wave synthetic aperture radar (SAR) with personnel screening applications, developed and implemented by the Northeastern University ALERT group. Millimeter-wave imaging systems are becoming prevalent for security applications where noninvasive imaging techniques are required to detect concealed objects. This is while the X-ray backscatter systems are becoming less favored due to ionization effects. The proposed radar system hardware is realized by a patented high gain Blade Beam reflector transmitting antenna, together with a low cost, highly integrated, wide-bandwidth 57-64 GHz transceiver chipset.

Nearfield imaging is performed by illuminating the human body target with millimeter waves and measuring the scattered field. The radar antenna system consists of a doubly curved reflector antenna with a circular curvature in azimuth and an elliptical curvature in elevation, creating a sharp beam in elevation and a wide collimated beam in azimuth. Using this doubly curved reflector antenna not only eliminates the need for a dense 2D complex array antenna configuration to realize a high-resolution imaging system, but also simplifies the 3D imaging into a set of 2D problems. The 3D image can simply be constructed by stacking the 2D images from different slices.

The experimental data proves the system capability to detect nonmetallic (explosive material) targets, as well as targets with dihedral effects. This is a great advantage over current state-of-the-art millimeter-wave portal imaging systems (monostatic systems) deployed in airports.

Student(s): Mohammad H. Nemati, Jacob Londa, Dan Busuioc, Spiros Mantzavinos, Graduate Student Research

Advisor(s): Dr. Carey Rappaport, Northeastern University

Center for Accelerating Operational Efficiency (CAOE)

Improving the Protection of Special Events Using Graph Analytics

Abstract: The protection of special events is a crucial problem both within the United States and globally. Currently, as analysts receive threat information pertaining to an event they must manually parse the threat information and then use traditional databases and search queries to understand the relationships and patterns between the new information and open source data or prior threats. This process is error prone, expensive and unscalable. In this poster, we present our initial work on constructing a Special Events Knowledge Graph (SEKG) for use by the DHS. A knowledge graph is an accessible graph-based database that contains relationships between elements derived from numerous disparate data sources.

When data is represented in a graph, consisting of vertices and edges with attached unstructured data, it becomes both natural for humans to understand and reason about as well as amenable for algorithmic analysis. Working with the DHS, FBI, and NYPD we have demonstrated this approach on a small-scale initial knowledge graph derived from 29 special event threat products. We created vertices from proper nouns in the products. Those vertices were labeled with categories, such as Media, Events, Groups, Individuals, Locations, and Threat. Edges were created when a report indicated a connection between two vertices. This resulted in a graph with 114 vertices and 163 edges that, even as a preliminary small-scale graph, provided insight into geographic relationships between attack types. We are continuing to ingest data from other sources and are developing novel predictive analytic techniques and algorithms designed specifically for analyzing the SEKG. Such a knowledge graph and predictive analytics will assist an analyst in making connections to aid in triaging and analysis and ultimately improve protection for special events.

Student(s): Kasimir Gabert, Doctoral Student Research

Advisor(s): Dr. David A. Bader, Georgia Institute of Technology

Development of a Real-Time Decision Support System for Proactive Response Under Uncertain Active Cascading Emergencies

Abstract: This research develops a proactive real-time decision system (RTDS) that will assist emergency responders in coordinating and responding to cascading disasters and emergencies (D&E). Natural disasters, such as hurricanes, wildfires, tsunamis, floods, and others, typically impact large areas and the impacts of such disasters cascade in time and space. When impact predictions can be made with little uncertainty, "what-if" scenarios can be developed and good response plans can be designed for each scenario. However, when predictions of impending D&E are highly uncertain, then a response strategy is needed where response actions are mobilized as the impacts of D&E events are learned and the cascading effects are dynamically predicted. The response strategy in RTDS focuses on three critical infrastructures (CIs) – transportation, (gasoline and diesel) fuel supply, and power systems and will be developed based on (1) probabilistic scenario trees, which are learned and enhanced in real time using observed data from observing and predicting the cascading dynamics, and (2) subsequent real-time decision analysis for recommending optimal response and recourse actions, as more and more is learned in time and space. This poster describes the conceptual framework of RTDS which models the cascading disaster impacts on all CIs and highlights the complex interconnectivities among the CIs. Furthermore, a visual prototype will be exhibited to further explain the design direction and outline how the response strategy on RTDS will be portrayed. The prototype will demonstrate the cascading disaster impacts and propose proactive response strategy over a hypothetical hurricane case study.

Student(s): Gita Ketut, Graduate Student Research

Advisor(s): Dr. Pitu Mirchandani, Arizona State University

Interdependencies & Cascading Effects of Disasters on Critical Infrastructure

Abstract: There are 16 critical infrastructure (CI) sectors whose assets, systems, and networks, whether physical or virtual, are considered so vital to the United States that their incapacitation or destruction would have a

debilitating effect on security, national economic security, national public health or safety. We advance analytic methodologies to investigate CI cyber-physical disruptions, their interdependencies, systems consequences and cascading effects. The results will offer insights that may influence guidelines and enable Infrastructure owners and operators to make informed decisions.

We model the critical infrastructures as a multi-layer network, with each layer corresponding to a CI sector, e.g., transportation, communication, healthcare, energy etc. In each layer, each node is a facility of the infrastructure which its layer represents. Each arc carries a probability and represents that the failure of the sourcing node may spread the failure to the ending nodes. The arcs in each layer model the cascading effect and interdependencies within an infrastructure; and the arcs between layers model these effects across different infrastructures. We use the influence maximization algorithm to determine the most critical nodes in each layer and across the entire network. For any given set of failed nodes, we use Monte-Carlo simulation to evaluate their cascading effects. The output will return the set of most critical/influential nodes measured by their overall cascading effects.

We demonstrate our model using two critical infrastructures: communication and energy. Our algorithm can identify the most critical nodes based on the overall cascading effects and impact on the population. We also identify the cascading nodes that could run into failure if the critical nodes fail. Thus, the critical nodes offer the best benefit for investment of preventive measures. Infrastructure owners and operators can utilize the model to determine the best investment of limited resources to minimize the cascading effects when part of the infrastructure network fails. The model is generalizable and can be applied broadly.

Student(s): William Wang, Graduate Student Research

Advisor(s): Dr. Eva Lee, Georgia Institute of Technology

Modeling the Gasoline Supply Chain in the Development of Real-Time Decision Support System for Proactive Responses under Uncertain Active Cascading Emergencies

Abstract: Although most of the models presented in humanitarian relief literature assume an uninterrupted supply of gasoline, this is seldom the case. Moreover, all other humanitarian relief supply chains depend on the gasoline supply chain. Without gasoline, it's impossible to transport first responders and critical resources such as food, water, and medicine to impacted areas. The primary purpose of this research is to develop a multi-stage stochastic model for the gasoline supply chain as an integral component of a more comprehensive real-time decision support system for proactive response under uncertain active cascading emergencies. The model uses real-time data to simulate uncertainty in gasoline supply and demand, and the gasoline supply chain infrastructure. Furthermore, the model will be able to determine the availability of gasoline, respond to rapidly changing needs for fuel, and arrive at fuel prepositioning strategies.

Student(s): Benjamin Morrow, Graduate Student Research

Advisor(s): Dr. Lauren Davis, North Carolina A&T State University

Coastal Resilience Center (CRC)

Advancing Modeling of Surface Winds During Hurricane Landfall for Predicting Storm Impacts

Abstract: Emergency managers and planners need to be better informed about the impacts of hurricanes in order to reduce risks for coastal communities. Researchers at the University of Rhode Island involved in the Department of Homeland Security (DHS) Coastal Resilience Center of Excellence develop new and improve existing modeling capabilities for assessing the potential impacts of land-falling hurricanes. Accurate modeling of surface winds during hurricane landfall is especially critical for predicting power outages and infrastructure damage over land and coastal flooding due to storm surges. As a hurricane moves from sea to land, the surface roughness it encounters abruptly increases causing significant changes to the structure of surface winds. Such changes include a rapid decrease in wind speed magnitude and a change in wind direction at the coastline. Parametric wind models commonly applied for wind damage assessment and storm surge models are typically too simplistic to sufficiently represent these complex wind structure changes. This study overcomes these limitations with a newly developed high-resolution hurricane boundary layer (HBL) model that incorporates the important physical processes in the three-dimensional dynamics equations. Simulations discussed in this study are of recent and historical hurricane events including Carol (1954), Bob (1991) and Irma (2017) as well as a hypothetical hurricane Rhody that was constructed using observations from past hurricanes. The HBL model results demonstrate significant improvements in the representation of the local wind magnitude and direction in comparison to the parametric model. These new capabilities will help to more accurately predict the impacts on critical infrastructure, utilities, and transportation during hurricane landfall.

Student(s): Catherine Nowakowski, Graduate Student Research

Advisor(s): Dr. Isaac Ginis, University of Rhode Island.

Strain-Based Approach versus Limit Equilibrium Analyses: Assessing the Effect of Hydraulic Loading History on the Stability of Princeville Levee

Abstract: Work in this study demonstrates the need for the paradigm shift toward using strain-based limit state analyses over conventional limit equilibrium approaches to investigate the stability of earthen levees. The Princeville levee and flooding from two past hurricanes Floyd and Matthew are used as case studies in which the analyses are focused on the effect of repeated rise and fall of water levels (representing the two storm cycles) on the stability of Princeville levee. The strain-based analyses are conducted using Plaxis 2D and the limit equilibrium slope stability analyses are conducted using Slope/W. The strain-based approach considered the uncertainty of the hydraulic conductivity of levee embankment and foundation layer. Results show a progressive development of plastic shear strain within the levee as the number of storm cycles is increased. The accumulation of such shear strain leads to increasing the probability of exceeding a given performance limit state, as demonstrated by the analyses results, and therefore reflects the increasing level of failure risk. On the other hand, the stability factors of safety obtained from limit equilibrium approach are not influenced by the number of water level rise and fall cycles. As such, the use of the limit equilibrium approach does not reflect the potential probability of failure with repeated loadings which negates the ability to use it in assessing risk levels associated with potential failure of earthen levees.

Student(s): Rowshon Jadid, Graduate Student

Research
Advisor(s): Dr. Brina Montoya and Dr. Mo Gabr, North Carolina State University, and Dr. Victoria Bennett, Rensselaer Polytechnic Institute

Criminal Investigations and Networks Analysis (CINA)

Joint Exploitation of Personal and Premises Surveillance Video

Abstract: Videos often provide useful information to investigate criminal occurrences. Relevant videos can be acquired from commercial or governmental security cameras, police car or body-worn cameras, and any "opportunistic" cameras that happen to have recorded the scene during the criminal activity. More cameras can enable a better reconstruction of the crime scenario. Our goal is to combine the information from multiple cameras by applying video processing and video analytics techniques for improved forensic investigations after the fact.

This range of input cameras can arise in a variety of scenarios where crimes may happen: at the airport, in a shopping mall or shopping center, a restaurant, a grocery store, or at sporting events or public festivals. In all these scenarios, both stationary and mobile cameras are likely. For example, consider a robbery outside at a public festival. The municipal surveillance cameras may capture the incident, and as the police arrive at the primary scene they acquire video using both vehicle-mounted cameras and body-worn cameras. During the investigation, videos from citizens' hand-held, vehicle, or body-worn cameras may also become available.

Each camera type brings advantages and disadvantages. Stationary surveillance cameras capture the entire environment, but the person of interest may have low visibility due to low resolution, blurriness, or poor environmental lighting. Vehicle-mounted cameras and mobile cameras may provide a clearer, higher-resolution view of the person of interest; however, they may not always be available, and when they are, they may not always point in the direction of interest or may have significant shakiness.

In this work, we develop a system that combines the information from all available cameras for forensic analysis. Our method allows an investigator to reconstruct, summarize and extract related information from any available videos based on the event of interest. Taking into account the quality of each video, we apply image retrieval and view synthesis to create a new view of the person of interest based on available data in response to an investigator's request. The stationary surveillance videos enable critical localization in time and space, while the additional videos can provide clarity and details.

Student(s): Biao Ma, Graduate Student Research
Advisor(s): Dr. Edward J. Delp, Purdue University

Critical Infrastructure Resilience Institute (CIRI)

Cyber Risk Scoring and Mitigation (CRISM)

Abstract: To uphold a secure IT infrastructure, risk assessment and mitigation are two dynamic process that needs to be performed in a timely manner. Attackers exploit software vulnerabilities and sneakily navigate host-to-host until they reach to a particular target. Within the network, there is a cause-consequence relationship among different states of the network. In past, attack graph and attack tree models have been proposed to assess the cause-consequence relationship. However, these risk

assessment models do not help to reason about the causal dependencies among network states. In order to address this issue, we implement a Cyber Risk Scoring and Mitigation (CRISM) tool, which can monitor the network to identify network vulnerabilities in a continuous manner. CRISM is developed based on a risk management framework using Bayesian networks, which helps a network administrator to effectively defend cyber-attacks by producing a quantifiable risk score. CRISM also helps a network administrator to achieve the goal of reducing the probability of successful attack. Before making any risk mitigation plan, the organizations need all sorts of trade-off related information in a resource-constrained environment. CRISM allows the organizations to choose the most efficient mitigation policies that can save a tremendous amount of time, effort and manpower.

Student(s): Md Ali Reza Al Amin, Graduate Student Research

Advisor(s): Dr. Sachin Shetty, Old Dominion University

Influence of a Resource Sharing Strategy on Business Recovery

Abstract: While there has been extensive discussion of resilience in general and some discussion of economic resilience in particular in the literature, the analysis of resilience actions (or tactics) aimed at reducing business interruption (BI) derived from natural disasters, and especially, measurements of the effectiveness of those tactics, have been relatively sparse. This is the case of a specific set of actions, resource sharing, which has been neglected in the literature. This study is the first to estimate economic resilience cost and effectiveness from a comprehensive and consistent set of empirical data obtained by a survey of businesses. Using data from a survey that was administered to businesses affected by Super Storm Sandy, this paper uses survival models to provide a quantitative analysis of the effects of different strategies, including resource sharing tactics, on reducing the time of post disaster business recovery. Results indicate that firms that utilized more effective resilience tactics recovered more quickly. This underscores the importance of this analysis: protracted recovery times can be avoided if firms understand ahead of time their most cost-effective resilience actions. As a consequence, it is of critical importance to policymakers, federal and state disaster and recovery organizations, as well as firms, to know which resilience actions provide the "most bang for the buck."

Student(s): Alfredo Roa-Henriquez, Graduate Student Research

Advisor(s): Dr. Noah Dormady, Ohio State University

Mapping Infrastructure Interdependencies for Improved Emergency Management and Resilience Investment Decisions

Abstract: Because of aging infrastructure components, vulnerability to natural disasters, and susceptibility to organized attacks, critical infrastructure systems are deteriorating and experiencing increased cascading failures. To enable municipalities to better understand their vulnerabilities and make informed decisions to increase resilience, we have developed a framework that maps interdependencies between infrastructures to support comprehensive risk assessments across multiple systems. The method creates a representative Bayesian network of interdependent infrastructure systems. Running analyses across the network over a range of threat scenarios allows users to assess infrastructure vulnerabilities and determine where to invest

resources to reinforce and recover infrastructure systems to improve resilience. Example scenarios include a hazard occurring in a specific geographic area, certain supply components failing, or an outage in a service area. We are able to include hundreds of component nodes in a computationally efficient manner without approximating assumptions. We also use the model to analyze component criticality within the infrastructure systems. Centrality-based and reliability-based component importance measures are analyzed. Centrality-based measures include degree centrality and those based on the system topology. Reliability-based measures include risk achievement worth, defining the impact of a single component outage on the probability of failure of the entire system. Through a collaboration with the City of Atlanta Office of Emergency Preparedness, we apply the methodology to assess critical water services in the City of Atlanta, Georgia, including dependencies of the distribution system on power and vulnerabilities to cyber attack. We validate the framework on an interdependent outage event and perform analyses that can be used to prioritize repair, replacement, and reinforcement of infrastructure components. The importance of considering interdependencies in critical component identification is analyzed. The water network is analyzed including and not including the dependency on the power system to assess how the critical components change based on the consideration of interdependencies.

Student(s): Chloe Johansen Applegate, Graduate Student Research

Advisor(s): Dr. Iris Tien, Georgia Institute of Technology

Using A Network Science and ArcGIS Approach to Enhance Resilient Critical Infrastructure Governance

Abstract: Critical infrastructure, as identified by the United States Department of Homeland Security, is vital to functioning and flourishing societies. As infrastructure has expanded over the past century, U.S. municipalities have become increasingly reliant on systems that spans across many jurisdictions, ranging from local to state-level and even national-level policy areas. Due to this interconnectivity, a disruption to one part of a system can quickly cascade across a city or region. In this research project, the Global Resilience Institute has developed an initial governance framework to assist with recovery of critical infrastructure in the face of a hazard as well as approaches to build resilience and safeguard assets before disasters take place. The framework includes: generating regional conversation about interdependence, learning lessons from other regions, and engaging public officials, private corporations, and regional associations. We propose the use of interactive mapping to locate critical infrastructure and disseminate information to stakeholders who might not yet be aware that they will be affected. As part of this research we use Boston as a case study to develop an initial critical infrastructure map, with the aim to scale the map to encompass the contiguous United States. In addition, we propose the use of a network science based mapping technique to simulate cascading hazards. Through these combined mapping techniques, our framework suggests equitable information distribution has the ability to create more resilient cities with lower maintenance and upfront costs. The distribution and use of our maps to locate resources and simulate loss of functionality provide a unique resource to decision makers prior to and during a hazard event, while our framework provides guidelines for engaging and informing stakeholders to improve disaster

response and pre-disaster mitigation.

Student(s): Mary Elizabeth Warner and Maria Ann Robson, Graduate Student Research
Advisor(s): Dr. Steve Flynn and Dr. Phil Anderson, Northeastern University

Maritime Security Center (MSC)

Exploring the Unknown for High Resolution Imaging

Abstract: When robots are tasked with mapping and exploring an unknown environment, their sampled point clouds can often be prohibitively large for real-time processing. The data can be reduced in size using grid-based map representations that catalog a robot's observations at lower resolution, such as occupancy grid maps. However, there may still be objects in the environment that we wish to map at high resolution, and most approaches for mapping and exploring unknown environments are intended to map the environment over a narrow range of spatial resolutions. This research focuses on perceptual and decision-making algorithms for exploring complex, large-scale marine environments quickly and efficiently, while mapping the structures of interest within these environments at high resolution. In the proposed approach, which employs multi-resolution Gaussian process occupancy mapping, and multi-objective decision making, the workload of processing of a robot's data can be divided among a server and the robot itself. The algorithm may be scaled to a swarm of robots that are deployed from a "mothership". This concept is being explored for the purpose of allowing unmanned underwater vehicles (UUVs) and remotely operated vehicles (ROVs) to deploy from an unmanned surface vehicle (USV) that serves as the mothership, to collectively inspect and explore port and harbor environments.
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Distributed Gaussian Process Temporal Differences for Cloud-based Robot Learning

Abstract: Our work studies the extent to which cloud computing can improve robot learning. Our objective is to apply robot learning to the control of multi-robot marine systems that are deployed in disturbance-filled port and harbor environments for surveillance, reconnaissance, inspection, and environmental monitoring. We consider Reinforcement Learning with Gaussian Process (GP) temporal differences, and we adapt this framework with distributable probabilistic models. The new models invoke episodic independence to split large datasets, collected over many learning trials, into smaller pieces which can be processed on remote computing systems. We propose two different methods for splitting the data. One method uses a simple sum of probability distributions, and the other uses a product. Robot control maneuvers are learned through experience using a novel actor-critic method that exploits our cloud-amenable models for efficient action selection. Our experiments compare the resulting methods to an actor-critic based on the standard GP model without cloud resources. We show our methods are able to process more data, and therefore, can solve complex problems which are too data intensive for the standard model. Beyond this study, we believe distributed learning merits ongoing focus. Individual robot learners can delegate intensive computations to expandable off-board resources. Furthermore, with our methods, collaborative robot groups can benefit from a principled information sharing

framework.

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Remote Multispectral Imaging-based Vessel Emissions Monitoring System

Abstract: Since January 8, 2009, U.S. and foreign-flagged vessels operating in the waters of the United States have been subject to Annex VI of MARPOL, which sets limits on sulfur oxides and nitrogen oxides emissions from ship exhausts, and prohibits deliberate emissions of ozone depleting substances. In a Memorandum of Understanding with the U.S. Environmental Protection Agency, the United States Coast Guard is responsible for the enforcement of MARPOL regulations. Currently, the USCG conducts enforcement through onboard compliance inspections. A remote, mobile vessel emissions monitoring system capable of identifying and quantifying ship exhausts, and determining fuel sulfur content can make enforcement much more efficient. Multispectral-sensing technology, which captures image data at specific frequencies across the electromagnetic spectrum, can be applied to enforce emission regulations. The thesis seeks to respond to the following research question: How can multispectral imaging technology be used to develop a vessel emissions monitoring system capable of remote and mobile operation? To develop the proposed vessel emissions monitoring system, the operational problem was first exposed. A literature review was then performed to determine the status of similar research conducted. The fundamentals behind multispectral technology carbon dioxide, sulfur oxides, and nitrogen oxides detection and quantification were then determined. A market survey was performed to determine if imagers suitable for vessel emissions were commercially available. A high-level system with a multispectral sensing-based imager was then proposed to complete the remote vessels emissions monitoring package. It was ultimately found that the proposed monitoring system has the potential to provide a small, lightweight, and efficient enforcement system for use on mobile enforcement platforms such as unmanned aerial vehicles, patrol boats, and smart buoys.

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Study of Terrorism and Responses to Terrorism (START)

A Typology for CVE Intervention Programming

Abstract: The goal of this literature review is to create an innovation typology with which to analyze countering violent extremism (CVE) programs worldwide. The new typology pulls from two existing frameworks: (1) the Responses to Intervention (RTI) Process, which is traditionally used for youth development; and (2) the "3 Ns" model of radicalization theorized by Dr. Arie Kruglanski and Dr. David Webber. RTI is a three-tiered model traditionally used for youth development and consists of three primary tiers for intervention. The first tier is Instructional Intervention, the second is strategic intervention, and the third tier is individual intervention. When applied to types of CVE programs, tier one is general education, tier two targets at-risk individuals, and tier three targets those who are already radicalized. The "3 Ns" model identifies the intersection of needs, narratives, and networks as critical to

radicalization. This model looks at these three factors in the contest of radicalization, where an individual has needs that motivate them to violence; narratives that justify violence; and social networks that they rely on while radicalizing. We look apply the "3 Ns" in a different context, and analyze how needs, narratives, and networks can be used to bring someone out of violent extremism. We examined over 40 CVE programs worldwide and categorized them by tier; then, we identified which of the "3 Ns" were being employed in each program. Some notable findings include: (1) the tier one programs we analyzed did not tend to address narratives, and (2) programs rarely addressed all three "Ns". This typology was then operationalized to identify intervention points in case studies of two extremists, Ariel Bradley and Wade Michael Page.

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Maryland Frame

Abstract: Within the past year, immigration has proven to be a particularly divisive American political and national security issue. Efforts to balance immigration, national security, and public safety have proven especially difficult. Universities, as incubators of debate, are well-suited to the task of determining innovative solutions to this human problem. The University of Maryland, College Park is a microcosm of the demographic trends shaping this country: according to a report released by the University's International Student & Scholar Services, 8000 foreign students representing five continents, dozens of disciplines, and an array of national origins study at UMD. Our organization, Maryland Frame, seeks to re-frame the discussion surrounding foreign students. Our mission is to normalize two groups of foreign students: international and undocumented students. Each group has a presence on campus and faces issues unique to them: social alienation, academic issues, and other obstacles to their successful integration. In raising awareness of these groups' experiences, we hope to empower them and their fellow students to increase the quality of life for foreign students. We intend to do this through several means. First, through a mobile-friendly website, we will expose non-immigrant students to international and immigrant related events, campus resources, and programs of study. Secondly, our program is geared toward culinary immersion; during our University's Maryland Day event, our team will run several booths showcasing diverse cuisines from around the world, while highlighting our campus' international communities. A cornerstone of our project is the research that we are conducting to better understand our target community: interviews, surveys and more help us to gain a nuanced view of the international community on campus. A grassroots program that engages foreign and non-foreign students through fun events can promote understanding and help to alleviate the feelings of tension that many in our target audience faces.

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