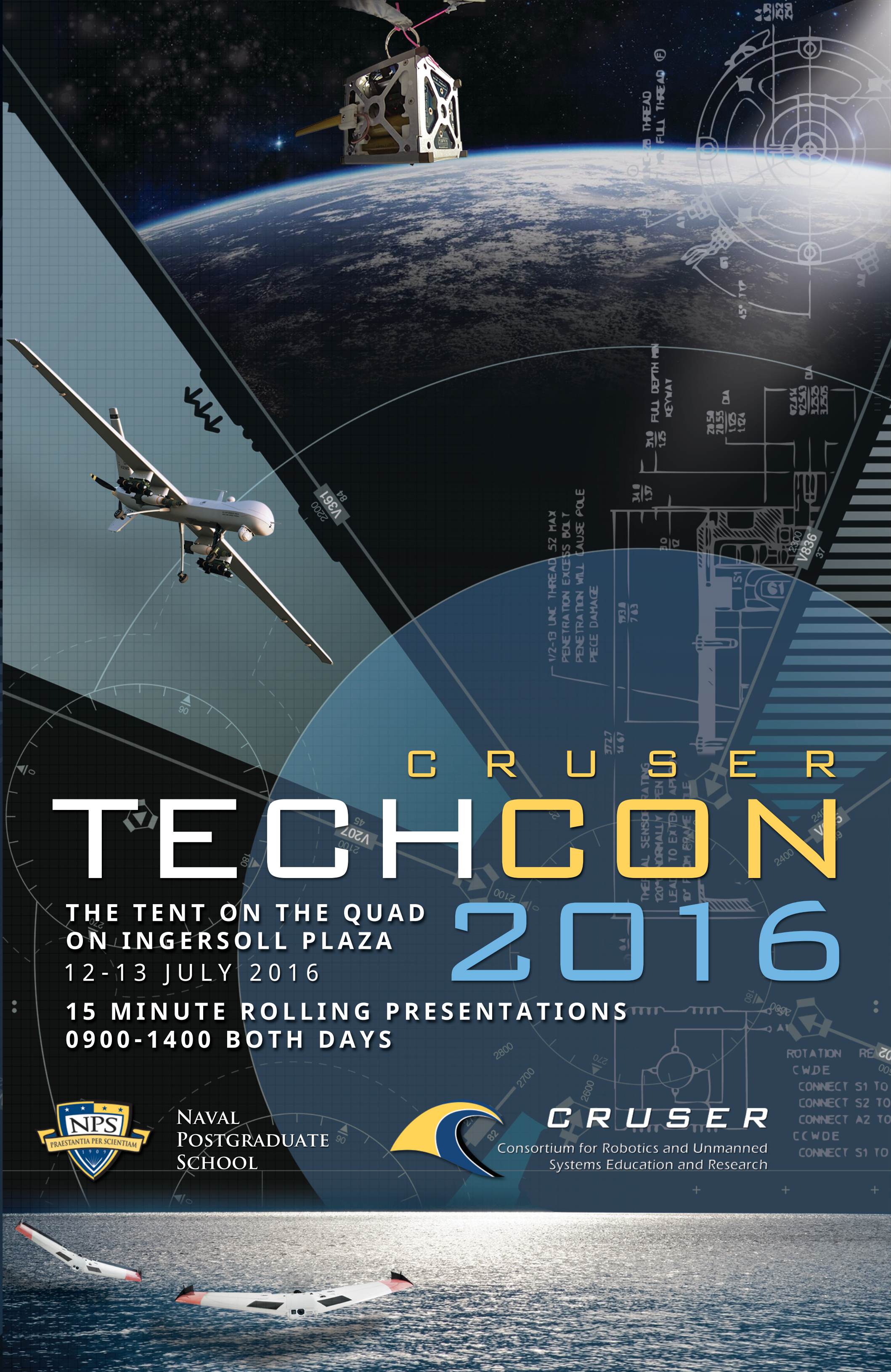
CRUSER
TECHCON 2016
THE TENT ON THE QUAD
ON INGERSOLL PLAZA
12-13 JULY 2016
15 MINUTE ROLLING PRESENTATIONS
0900-1400 BOTH DAYS
NPS
PRAESTANTIA PER SCIENTIAM
Naval Postgraduate School
CRUSER
Consortium for Robotics and Unmanned Systems Education and Research

Tuesday 12 July 2016

0900 Dr Ray Buettner, CRUSER Director - Welcome

0905 C. Blais: NPS MOVES - Government-Owned Software for Robotics Education and Research

0925 C. Blais: NPS MOVES - Challenges in Distinguishing Manned from Unmanned Systems in Combat Models

0945 R. Gramache: NPS PH - Electric Gun System

1005 E. Gyde: BATTELLE - Interactive 360 Video for Autonomous and Unmanned Platforms

1025 J. Reeder: SSC-Pacific - Path Integral Control with Evolved Cost Functions for Control of Agile UAV Swarms

1045 K. Song: NPS OC - Prototype Basic MCM UUV Search Mission Management AI Module Integration

1105 D. Brutzman/D. Davis/C. Blais/R. McGhee: NPS MOVES - Ethical Mission Tasking and Execution for Maritime Robotic Vehicles

1125 D. Mortimore: NUWC Keyport - NUWC Division, Keyport Unmanned Systems Research and Experimentation Opportunities

1145 H. Park/Tavora Romano/Yun: NPS MAE/ECE - Project MANICOPTER: Autonomous Aerial Vehicles with Robotic Manipulation Capability

1205 J. Virgili-Llop/M. Romano: NPS MAE - Modeling and control of UxV with onboard robotic manipulators of similar size

1225 K. Jones: NPS MAE - Aqua-Quad: Status and Future Developments

1245 W. Kang: NPS MA - Observability and Optimal Sensor Placement for Mobile Sensor Networks

1305 D. Boger/ S. Miller: NPS IS - Using Co-Active Design to Implement Marine Machine Interdependence in Squad Maneuvers

1325 F. Alves: NPS PH - Bio-inspired MEMS acoustic sensor for robotic autonomous systems applications"

1345 S. Fahey: NPS CS - USV for Maritime Shield

1405 S. Kragelund: NPS MAE - Experimentation in Extreme Environments: Recent Results by CAVR

Wednesday 13 July 2016

0900 Dr. Brian Bingham: CRUSER Deputy Director - Welcome

0905 B. Bingham: NPS MAE - Developing Single Sortie Detect to Engage Multi-Vehicle Autonomy with Ground-Based Testbed

0925 J. Joseph: NPS OC - Acoustic characterization of the new Arctic using unmanned systems in ICEX-16

0945 Y. Kwon/J. Klamo: NPS SE/MAE - Unsteady loads on UUV during near surface operation

1005 P. Thulasiraman: NPS ECE - Evaluation of Security Algorithms in Cyber Defense of UAV Swarm Communications

1025 G. Xie: NPS CS - Reliable Ad-hoc Communication through Multi-path Data Delivery

1045 D. Brutzman: NPS IS/USW - RoboData Archive for JIFX/CRUSER Unmanned System Experimentation

1105 J. Testa/V. Dobrokhodov: NPS MAE - Vision-Based Relative Navigation of Multicopter UAV in Maritime Interdiction Operation

1125 X. Yun/ J. Calusdian: NPS ECE - MATLAB Interface for the P3-DX Mobile Robot

1145 C. Walton/ I. Kaminer: NPS MAE - Optimal Sensor Deployment and Information Gathering using UxSs

1205 J. Metcalf/R.C. Olsen: NPS PH - Photogrammetric Point Cloud Fusion Using UAV Collected Thermal Imagery

1225 E. Kartalov: NPS PH - Microfluidic System for Sample Collection by Air Drones for Biohazard Defense and Remote Monitoring of Epidemics

1245 E. Kartalov: NPS PH - Conceptualization Study of Unmanned Remote-Crewed Armored Fighting Vehicles

1305 P. Guest: NPS MR - Using Quad-rotor UAS to Perform Meteorological Measurements From Ships

1325 S. Sanchez : NPS OR - Closing Capability Gaps: Data Farming Methods for New Concept Exploration in the CRUSER Community

1345 S. Kragelund/ C. Walton/ I. Kaminer: NPS MAE - Sonar Detection Mission Planning Tool for Autonomous Vehicle Teams

1405 D. Brutzman: NPS IS/USW - QR and DFL Optical Communications for Network Optional Warfare (NOW)

Mr Curtis Blais
NPS Modeling, Virtual Environments and Simulation Institute

Title: Government-Owned Software for Robotics Education and Research

Abstract:
The Office of the Secretary of Defense Joint Ground Robotics Enterprise (JGRE) is actively promoting enrichment of robotics education and research in the Department of Defense. Under JGRE sponsorship, NPS is obtaining several software packages for use in education and research. These include: (1) Virtual Autonomous Navigation Environment (VANE), a high-fidelity, physics-based program developed by the US Army Engineer Research and Development Center (ERDC) for simulating terrain and environmental conditions and the ways they impact sensor performance; (2) Advanced Navigational Virtual Environment Laboratory (ANVEL), software developed by ERDC providing a 3D visualization environment for VANE; and (3) Advanced Explosive Ordnance Disposal Robotic System (AEODRS), a software framework for a family of systems being developed by the US Navy for joint operational deployment. This presentation will provide a brief overview of these software packages and coordination efforts to introduce the products into NPS robotics research and education.

Notes:

Mr Curtis Blais
NPS Modeling, Virtual Environments and Simulation Institute

Title: Challenges in Distinguishing Manned from Unmanned Systems in Combat Models

Abstract:
Unmanned systems are changing the nature of future warfare. Combat simulations attempt to represent essential elements of warfare to support training, analysis, and testing. While combat simulations have rapidly incorporated representations of unmanned systems into their capabilities, little has been done to distinguish unmanned systems from human systems in these simulations. This is making it difficult to impossible to consider questions of future manned/unmanned system mix, levels of unmanned system autonomy required for most effective operational success, and other relevant questions. One might think that replacing humans with fully autonomous unmanned systems, such as in unmanned convoys, results in identical mission performance with the added benefit of a decrease in loss of human life. However, this is a naïve line of reasoning when one considers that unmanned systems cannot react to the battlespace environment with the same level of flexibility as humans. Unfortunately, we have not yet been able to capture such distinctions in combat models. This presentation discusses the challenges we face in developing improved models of human systems, unmanned systems, and human-robot teams in combat simulations, with examples posed in the context of the Combined Arms Analysis Tool for the 21st Century (COMBATXXI), a discrete-event simulation developed and employed by the U.S. Army and U.S. Marine Corps to address analytical questions about future warfighting capabilities.

Notes:

Prof Raymond Gamache
NPS Physics Department

Title: Electric Gun System

Abstract:
Alternative to standard percussion based mechanical firing gun systems, a new electronic fired gun system having no mechanical parts is proposed. An in-line projectile system, very different from the previous Metal Storm concept, incorporates electric primed bullets initiated through a conductive network integrated within the projectile system. Key benefits include reduced weight, low power requirements, direct interface to command control modules, round count, fire status, salvo selection, avoidance of mechanical jams and remote round clearing capabilities.

The proposed gun system can enable multiple barrels with different projectile types (lethal, non-lethal, HE, smoke, …) to be integrated within a single module and directly interfaced to an operator command and control interface.

First year efforts would incorporate the design and construction of a single Mann barrel gun and projectile system. A demonstration of the ability to fire 6 in-line projectiles sequentially will be performed.

Notes:

Ms Emily Gyde
Battelle

Title: Interactive 360 Video for Autonomous and Unmanned Platforms

Abstract:
Battelle's HorizonVue M360 Video System is used to capture high resolution 360 video from manned or unmanned platforms to provide greater situational awareness to the operator and inputs to autonomous systems. As the technology evolves, there are growing opportunities to leverage these sensors for real time data manipulation to drive autonomous behaviors. Battelle, in collaboration with its wholly owned subsidiary SeeByte, is currently testing Automatic Target Recognition algorithms within the 360 imaging software to track objects above and below water, as well as function as a passive positioning and navigation sensor. Machine vision functionalities, such as reading QR codes to drive behaviors, have only begun to be utilized with wide angle imaging techniques. Many areas remain to be explored that can produce enabling capabilities.

The low size, weight and power of the camera and lens configuration uniquely position the technology to be used by small unmanned aerial vehicle's that cannot support heavy, power hungry pan and tilt units. Unlike fisheye lens approaches, the majority of the pixels are distributed on the horizon of the platform's field of view: opening the door for use in SWARM applications with multiple platforms. These cameras have no moving parts, and the software has been built to support multiple virtual pan, tilt, and digital zoom (PTZ) windows. The use of video over Ethernet streaming allows the host computer controlling the camera to distribute the raw data to multiple other users or machines. This architecture allows those users to uniquely configure their own displays and manipulate virtual PTZ windows independent of others accessing the feed.

The opportunity exists to integrate this imaging technology with platforms that are in use by NPS programs to develop capabilities for future autonomous and unmanned solutions. Our imaging systems utilize core technology developed through ONR programs and continue to be demonstrated on platforms such as Boston Engineering's GhostSwimmer AUV at the recent Trident Spectre event.

Notes:

Dr John Reeder
NPS SSC

Title: Path Integral Control with Evolved Cost Functions for Control of Agile UAV Swarms

Abstract:
Cheap, agile swarms of unmanned systems, including unmanned aerial vehicles (UAVs), are increasingly relevant technologies in today's battlefront. Large numbers of small, expendable UAVs with acrobatic agility can be launched as a swarm in order to combat other swarms of UAVs, create an array of sensors, or deploy electromagnetic warfare measures. Autonomous control and coordination of such swarms remains a difficult problem. Here we demonstrate an optimal control method known as Path Integral (PI) optimal control to provide a robust, scalable, and distributed solution to this problem. PI control is a sampling based optimal control algorithm which utilizes sampling of multiple future trajectories to calculate the optimal path and controls. Applying this algorithm in a centralized fashion to control a large swarm of UAVs may be computationally prohibitive. However, if UAVs can share their planned trajectories with each other, a distributed version of the PI control is computationally tractable and scalable for any number of UAVs. Should communications be jammed or lost, onboard sensing and estimation can instead be used and incorporated into the PI control algorithm to achieve close to optimal behavior. The task to be accomplished is specified by designing a cost function which the PI control algorithm tries to minimize. Sometimes these cost functions can be hand designed if the task is simple or specific enough. However, for more complex scenarios, hand designing may become difficult or time consuming. We therefore incorporate the use of a genetic algorithm known as NeuroEvolution of Augmenting Topologies (NEAT) to evolve cost functions for the PI control algorithm to use. Using the cost functions evolved by the NEAT algorithm, we demonstrate the control of swarms of UAVs in a simulated swarm vs swarm combat scenario. The result is a robust planning algorithm that scales well for a large number of UAVs to accomplish a unified task, while incorporating agile and acrobatic UAV flight dynamics.

Notes:

Mr Kwang sub Song
NPS Oceanography Department

Title: Prototype Basic MCM UUV Search Mission Management AI Module Integration

Abstract:
This Project is focused on the development of enabling technologies for the reliable and robust mission operation of highly automated autonomous vehicles. Future vehicle capabilities will expand from the current pilot-centric model with way points to include autonomous vehicles. These new capabilities will enable all autonomous vehicles to operate seamlessly in a fully integrated autonomous vehicles system that maximizes mobility and combat effectiveness, opens new commercial markets, provides f high level of autonomy systems in homeland security and defense missions.

Developing intelligent on-board mission management systems with a high degree of self-awareness and reduced levels of human interaction in search missions of MCM UUV is a major challenge for this project. Functions typically performed by highly skilled pilots and maintenance personnel will be automated with the goal of achieving higher system reliability, and greater vehicle utilization by a much broader segment of the population.

Mission management system module is comprised of five Sub-Projects, three of which are considered mid/high technology readiness level (TRL) activities. One of the mid/high TRL Sub-Projects within this project is Artificial Intelligent Mission Management System (AIMMS). The objectives of AIMMS are to develop autonomous vehicle and associated control center element technologies to:

1. To implement tactical mission success
2. New S/W missions' module, which are independent from autonomous platform
3. Increase science return while reducing workload with plug in, and operational costs

This work would be basic building block for genuine AI applied mission management module for future MCM UUVs.

Notes:

Prof Don Brutzman/Curtis Blais/Robert McGhee/ Duane Davis
NPS Information Sciences Department/Undersea Warfare

Title: Ethical Mission Tasking and Execution for Maritime Robotic Vehicles

Abstract:

Many types of robotic vehicles are increasingly utilized in both civilian and military maritime missions. Some amount of human supervision is typically present in such operations, thereby ensuring appropriate accountability in case of mission accidents or errors. However, there is growing interest in augmenting the degree of independence of such vehicles, up to and including full autonomy. A primary challenge in the face of reduced operator oversight is to maintain full human responsibility for ethical robot behavior.

Informed by decades of direct involvement in both naval operations and unmanned systems research, this work presents a new mathematical formalism that maintains human accountability at every level of robot mission planning and execution. This formalism is based on extending a fully general model for digital computation, known as a Turing machine. This extension, called a "Mission Execution Automaton" (MEA), allows communication with one or more "external agents" that interact with the physical world and respond to queries/commands from the MEA while observing human-defined ethical constraints.

An important MEA feature is that it is language independent and results in mission definitions equally well suited to human or robot execution (or any arbitrary combination). Formal description logics are used to enforce mission structure and semantics, provide operator assurance of correct mission definition, and ensure suitability of a mission definition for execution by a specific vehicle, all prior to mission parsing and execution. Computer simulation examples show the value of such a "Mission Execution Ontology" (MEO).

The flexibility of the MEA formalism is illustrated by application to a prototypical multiphase area search and sample mission. This effort presents an entirely new approach to achieving a practical and fully testable means for ethical mission definition and execution. This work demonstrates that ensuring ethical behavior during mission execution is achievable with current technologies and without requiring artificial intelligence abstractions for high-level mission definition or control.

We are now looking for 1-2 thesis students interested in investigating critical mission-essential tasks performed by each Navy warfare community. Next steps will define mission goals and constraints in a semantically validatable way, using simulation to demonstrate how unmanned systems can be ethically tasked in support of naval aircraft, ships and submarines.

Notes:

Mr David Mortimore
NUWC Keyport

Title: Unmanned Systems Research and Experimentation Opportunities

Abstract:
In conjunction with Department of Defense (DoD), University Affiliated Research Centers (UARCs) and other organizations, Naval Undersea Warfare Center (NUWC) Division, Keyport is involved in advancing the Warfighter's ability to plan, employ, and use the data and information collected by multi-domain and single domain unmanned systems. One of the command's missions is to perform test, training, experimentation, and evaluation work during all stages of the Systems Acquisition Process. That requires the command to understand, and potentially design install land-based and at-sea based performance systems while the approaches to unmanned systems design, adaptive autonomy, communications, cybersecurity, precision navigation and timing, and other capabilities continue to evolve. Additionally, the command's fixed three-dimensional undersea tracking ranges and portable undersea tracking ranges are part of the DoD's Major Range and Test Facility Base architecture, and used for research, experimentation, Fleet training, and other purposes.

The brief will provide an overview of NUWC Division, Keyport, some of its at-sea and land-based capabilities in the Pacific Northwest, Southern California, Hawaiian, and Guam areas, proposed research and experimentation focal area priorities, and potential opportunities for NPS faculty, staff, and students. Additionally, through its relationship with Navy-sponsored UARCs, research and experimentation efforts are able to integrate representatives and capabilities from those organizations.

Notes:

Dr Hyeongjun Park/Capt Tavora/Prof M. Romano/Dr Yun)
NPS Mechanical & Aerospace Engineering/Electrical & Computer Engineering Departments

Title: MANICOPTER: Autonomous Aerial Vehicles with Robotic Manipulation Capability

Abstract:
Physical interaction with the environment enables to extend utilization of Unmanned Aerial Vehicles (UAV) to conduct various missions such as grasping, object picking and assembly, data acquisition and inspection by contact objects or surface. In this project, we investigate the dynamics, guidance, and control of autonomous air vehicles with robotic manipulation capability for the physical interaction with other objects. Mission scenarios of picking up and delivering, door opening, and data acquisition on surface are considered.

Toward this goal, we have developed an experimental platform of a hexacopter with a robotic arm. Results of the first year effort for aerial manipulation will be presented. To analyze the system dynamics when the hexacopter contacts with the environment, modeling and parameter identification of the hexacopter with a manipulator have been studied. A novel method using a compound pendulum and an optical position tracking system, Vicon, to identify parameters (e.g., moments of inertia, engine thrust, and aerodynamic drag torque) for the hexacopter has been proposed and validated through flight experiments. Simulation works for dynamics, guidance, and control of the aerial manipulation system have been implemented as well. Two layer-controllers have been developed for translational motion and attitude stabilization of the hexacopter based on PID and LQR controllers. The motion of the base and the robotic arm has been analyzed to develop a feed-forward compensation controller which avoids large movement when parameters such as the center of mass and moment of inertia change while the robotic arm moves to implement tasks.

Ongoing research effort for flight experiments and plan in FY17 are also discussed. To verify the arm static compensation controller for the aerial manipulation system, flight experiments are in progress. An estimator of external generalized force when the robotic arm interacts with the environment will be also developed to improve the controller. With this multi-layer control algorithm we will implement missions to pick up and deliver an object to a certain point, to contact the vertical surface and objects on the wall, to stay near the wall and conduct tasks such as door opening and surface inspection. In FY17, propose efforts are to continue experimental testing and analyzing control methods such as model predictive control and L1 adaptive control. In addition, investigation of rendezvous and proximity maneuvering of two multicopters is proposed in corporative and/or countermeasure missions.

Notes:

Dr Josep Virgili-Llop/Prof M. Romano
NPS Mechanical and Aerospace Engineering Department

Title: Modeling and control of UxV with onboard robotic manipulators of similar size

Abstract:
When a robotic manipulator is attached to a moving base (i.e. not fixed), a dynamic coupling between manipulator and the base motion emerges. The reaction imparted to the base due to the manipulator motion is usually not desired and thus it either needs to be minimized or compensated for, thus making the control of the system a more challenging task. Increased dynamic coupling is obtained when the base is relatively small (in terms of mass and inertia) when compared to the manipulator. Due to this dynamic coupling and the inherent non-linear manipulator mechanics these systems are complex to model and difficult to control.

To experimentally investigate and validate modeling and control approaches for robotic manipulators mounted on relatively small moving bases, a planar four degree-of-freedom manipulator has been developed to be used in conjunction with the Floating Spacecraft Simulator testbed at the Spacecraft Robotics Laboratory. The combined system (base and manipulator) kinematically and dynamically recreate the space environment in two translation and one rotational degree-of-freedom. This experimental set-up allows to investigate the dynamics and control of spacecraft-mounted manipulators and rehearse complete mission scenarios (e.g. capture of an uncooperative space object). With a total manipulator mass very similar to the mass of base-spacecraft and with a much larger inertia (when fully extended) the dynamic coupling of this particular system is highlighted.
Each link of this custom developed manipulator is modular and thus it can be quickly re-assembled into different configurations to adapt to different test requirements. After a thorough kinematic and dynamic calibration the system is ready to be utilized to investigate modeling and control of spacecraft-based manipulators.
Additionally, an open-source MATLAB and Simulink toolkit (named SPART), that is capable of modeling generic robotic manipulators mounted on moving bases has been developed. Unlike generic physics engines, the toolkit provides, through numerically efficient recursive algorithms, all the system's kinematic and dynamic entities (including inertia matrices) as well as inverse and direct dynamic solvers. The toolkit has been developed so that efficient C code can be automatically generated and executed in real-time on embedded hardware (e.g. onboard the Floating Spacecraft Simulators).

A custom designed manipulator to be mounted on the Spacecraft Robotics Laboratory indoor flying multicopters will also be developed, and thus extend the testing capabilities to a full six degrees-of-freedom environment.
The ultimate goal of this effort is to generate and experimentally validate a wide range of modeling and control algorithms for robotic manipulators mounted on relatively small moving bases for a wide spectrum of autonomous terrestrial, air and space applications.

Notes:

Dr Kevin Jones
NPS Mechanical and Aerospace Engineering Department

Title: Aqua-Quad: Status and Future Developments

Abstract:
Funded by CRUSER in FY14 and FY15, the Aqua-Quad is a concept platform intended for long-endurance hybrid-mobility underwater sensing; essentially coupling the sensing capabilities of a Sonobuoy with the agile mobility of a quad-rotor aerial vehicle. Drawing from technologies developed under the Tactical Long Endurance UAS (TaLEUAS) project (CRUSER FY12/13), the Aqua-Quad is energy independent, meaning that all energy required for operations is absorbed from the environment in the forms of Solar photovoltaic energy, and wind and water currents, allowing it to operate for months at a time without any form of replenishment or human intervention. The team now has a flying prototype, and is seeking an interim flight clearance to allow for autonomous operations of the solar-recharged flight vehicle. A non-flyable model has been deployed on the Monterey Bay to evaluate sea-worthiness, and the ability to keep the solar-array above water in heavy, but non-breaking swells. Student research projects have included hybrid-mobility aspects; minimizing energy consumption for point-to-point travel using optimal drift and flight segments, use of the platform for underwater sensing with Acousonde, and development of a compact, high efficiency Maximum Power-Point Tracker (MPPT) and charge controller for converting solar energy into stored energy. For the upcoming year, the team plans to demonstrate repeated full autonomous flights with solar-recharging between hops, complete the water hardening of the prototype for at-sea take-off and landing, algorithms and embedded software to control cooperative and teaming behaviors of teams of vehicles, and begin development of suitable tethered underwater vector sensors. The team is expanding to include members of NPS Physics, and a newly formed cooperative effort with NAVSEA Keyport.

Notes:

Prof Wei Kang
NPS Mathematics Department

Title: Observability and Optimal Sensor Placement for Mobile Sensor Networks

Abstract:
Unmanned vehicles have been increasingly used as effective platforms of mobile sensors for a wide spectrum of applications, such as marine and weather forecast, searching and tracking of military targets, and pollution monitoring. Mobile sensors are used in a number of recent CRUSER projects. The objective of this project is to develop and validate the concept and numerical algorithms for the purpose of maximizing the value and the effectiveness of data collected by sensor network, through optimal path planning and feedback control of mobile sensors. More specifically, the technical objectives include: (1) defining the concept of observability for networks of heterogeneous mobile sensors; (2) developing a mathematical model for the optimal path planning and optimal control of mobile sensors; (3) developing computational algorithms of optimal path planning and optimal feedback control; (4) exemplifying the theory and algorithms using two examples, intrusion detection by UAVs and data assimilation of shallow water dynamics.

Notes:

Prof Dan Boger/Prof Scot Miller
NPS Information Sciences Department

Title: Using Co-Active Design to Implement Marine Machine Interdependence in Squad Maneuvers

Abstract:
Unmanned tactical autonomous control and collaboration (UTACC) is a Marine Corps experimental research initiative with the overarching aim of developing a collaborative human-robotic system of systems (SoS). Our research analyzed the results of the existing UTACC concept development and incorporated them into an emergent human-robotic system development method, Coactive Design.
An advantage to using this method is that it includes the human and his or her internal processes when modeling the system. As such, the focus is shifted to supplementing team capacities vice developing autonomy.

The two aims of this research are (1) to provide a recommendation for incorporating the Coactive Design method into the systems' development life cycle and (2) to provide a list of design requirements for a resilient UTACC SoS. Resilience is realized by designing for flexibility. A teamwork infrastructure built on many interdependent relationships provides this flexibility. These interdependent relationships can be grouped into three areas: observability, predictability, and directability. Counter to conventional practices within the robotics industry, Coactive Design focuses on managing these interdependencies rather than focusing on autonomy.

This talk will present how we will use Coactive Design to enable the UTACC system to design for mission resilience in squad and below Marine-machine interactions.

Notes:

Dr Fabio Alves
NPS Phyics Department

Title: Bio-inspired MEMS acoustic sensor for robotic autonomous systems applications

Abstract:
What makes acoustical awareness in robotic autonomous systems (RAS) difficult is the underlying complexity of the acoustical domain. The soundscape is always changing with time, and the sensors currently available for sampling it are noisy and only capture a relatively small selection of the soundscape. Additionally, the auditory scene itself is not straightforward, and varies significantly from environment to environment, even when the same types of noise and sources of interest are present. Altogether, this creates a very hostile perceptual domain for RASs, which are already struggling to successfully handle routine many other tasks. One attractive solution is to have signature-based sensors in order to detect the sources of interest while naturally filtering any other acoustic perturbation. Our research group has developed a narrowband acoustics sensor, using microelectromechanical systems (MEMS) technology, based on the mechanically coupled ears of the Ormia Ochracea fly. The sensor consists of two wings coupled at the middle and attached to a substrate using two legs. The sensor operates at its bending resonance frequency that can be tuned to the sound source of interest, and has cosine directional characteristics similar to that of a pressure gradient microphone, allowing for the sound source localization. The sensors can be designed and configured to provide signature-based acoustic response in addition to non-ambiguous determination of the direction of sound. Our results show high sensitivity (~ 25 V/Pa) and high accuracy in direction of arrival determination (~ 3 deg), all achieved with small size devices (few millimeters) and low power consumption (~15 mW). Recent field test performed during the last JIFX in Camp Roberts showed a remarkable ability to determine direction of gunshots at great distances. We believe that the MEMS acoustic sensor can be used in RASs applications in two ways. First as part of the sensor rig to provide acoustic awareness and localization of desired sources. Second, new sensors can be designed based on RASs acoustic signatures to provide identification capability to be explored in counter RAS threats or cooperative operations such as swarm robotics.

Notes:

LT Stephen Fahey
NPS Computer Science Department Student

Title: USV For Maritime Shield

Abstract:
ASW USVs have been proposed as a means for protecting strike groups against attack submarines. Methods of employing USVs for this purpose need to be detailed and evaluated. This study is focusing on the mission of defending a High Value Unit (HVU) while in MODLOC (Miscellaneous Operational Details, LOCal operations), and while in transit between MODLOCs. These missions are also known as Maritime Shield and Protected Passage. Theoretical analyses will be validated via modeling and simulation of typical scenarios to determine feasibility and practicality of proposed approaches. Ongoing research is addressing the following questions:

1. What USV employment approaches best support ASW CONOPS "Maritime Shield" and "Protected Passage"?
2. How many USVs, sensors, and other resources are needed for each scenario?
3. What kind of interactions will the USVs need to have with other platforms in these contexts and what degree of human operator control will they need?
4. Which aspects of these missions could the USVs carry out autonomously and what kind of autonomous decisions will be needed to carry out the missions more effectively than with current manned platforms?
5. How can we determine the value added by autonomy and decide which aspects of the USV mission would benefit most from automation?

By using surprise to its advantage, a submarine can devastate a surface group with its weapons or cause chaos by its presence (or threat thereof) alone. This is of great advantage to an enemy who seeks to disrupt or destroy his opponent at minimal cost. The submarine is a force multiplier for the power that wields it. Technology helps make submarines quiet, and with a properly trained and proficient crew, a modern diesel-electric submarine is VERY quiet. When silence is combined with a noisy underwater environment, a diesel-electric submarine becomes nearly impossible to detect with the relatively few sensors that can be employed against them. Coupled with longer endurance times (less need to surface and recharge batteries), submarines give a surface force minimal opportunities for detection.

The Unmanned Surface Vehicle is a potential equalizer. Increasing the number of sensors in the water will usually lead to an increase in the probability of detection. Ideally, these sensors should be inexpensive and recoverable. An added bonus would be if they could be repositioned once deployed (a limitation of sonobuoys – they only drift with currents). A USV can potentially improve this situation by providing a mobile sensor platform that augments other platforms. This leads to the challenge: understanding the trade-space of autonomy, sensing, and communication capabilities, that actually enhance an ASW commander's situational awareness without contributing to sensory or manpower overload?

The answer to this question is critical because the consequences of failure are so severe. With each new generation of submarine, the risk increases and needs to be mitigated. USVs could provide some mitigation relief.

Mr Sean Kragelund
NPS Mechanical and Aerospace Engineering Departments

Title: Experimentation in Extreme Environments: Recent Results by CAVR

Abstract:
The NPS Center for Autonomous Vehicle Research (CAVR) conducted multiple CRUSER-sponsored research projects in FY16, culminating in two exciting field experiments. In July 2015, CAVR traveled to Florida for NASA's Extreme Environment Mission Operations (NEEMO) XX experiment at the Aquarius underwater habitat near Key Largo. At NEEMO, CAVR deployed its REMUS 100 autonomous underwater vehicle (AUV) to map the underwater environment with sidescan sonar and multi-beam bathymetry sonar. Initial surveys identified areas with prominent features on the seafloor so CAVR researchers could generate feature maps for terrain-aided navigation (TAN) algorithms. This navigation strategy is especially useful on the Agile Close Quarters Underwater Autonomous System (ACQUAS), a tethered AUV that CAVR has developed as a collaborative robotic diver assistant. Designed to operate in close proximity to structures and human divers, ACQUAS demonstrated its effectiveness during several cooperative missions with NASA aquanauts.

Terrain-aided navigation is also a key enabler for extended AUV operations in polar environments, since vehicles are unable to surface through the ice for a GPS fix to correct accumulated navigational errors. In March, CAVR researchers and students traveled to Ice Camp SARGO, situated on a drifting ice floe in the Arctic Ocean, to conduct under-ice operations with REMUS and ACQUAS during the U.S. Navy's Ice Exercise (ICEX) '16. ICEX is a five-week exercise designed to research, test and evaluate operational capabilities in the Arctic region. CAVR's primary objective was to test algorithms for navigating under the ice when the vehicle's local navigational reference frame, anchored to a position on a moving ice floe, changes over time.

In this presentation, we will highlight some of the unique challenges of operating autonomous vehicles in these extreme environments. We will also share recent developments and lessons-learned from CRUSER-sponsored research programs and field experiments, including a preview of NEEMO XXI, currently underway, where several CAVR researchers and students are playing an important role.

Notes:

Dr Brian Bingham
NPS

Title: Developing Single Sortie Detect to Engage Multi-Vehicle Autonomy with Ground-Based Testbed

Abstract:
TThe goal of the detect to single sortie detect to engage (SS-DTE) program is to create a capability for an unmanned surface vessel (USV) to deploy, recover and sustain multiple unmanned underwater vehicles (UUVs) to support mine countermeasures (MCM). Conceptually, this solution will consist of a 40 ft USV host craft carrying 4 lightweight UUVs and 24 expendable neutralizers – along with the requisite support gear. Because this team of robotic vehicles will operate for extended time with limited communication, development of suitable autonomy for each phase of the mission is a critical component of the system.

This presentation describes a ground-based testbed for rapid prototyping of multi-vehicle autonomy solutions for SS-DTE. The testbed, serving as an embodied simulation, fills an important gap between virtual simulation and field implementation. Because the testbed consists of a team heterogeneous robots, it adds a increment of authenticity (and complexity) not easily captured in existing virtual environments. Because the testbed is ground-based, it provides a cost-effective facility for agile development, reducing the barrier to incremental performance testing. However, neither an embodied or virtual simulation can capture the full complexity of such a system; we discuss these limitations and propose how the testbed can be used to effectively support SS-DTE multi-vehicle autonomy development.

Notes:

Prof John Joseph
NPS Oceanography Department

Title: Acoustic characterization of the new Arctic using unmanned systems in ICEX-16

Abstract:
Recent changes in the Arctic environment mean that operational databases have become more uncertain and operational TDAs can be expected to perform poorly in the "new" Arctic due to poor environmental input and lack of understanding of the acoustic phenomena. This may lead to improper placement of assets/sensors and potential exposure to shorter than expected counter-detection ranges. Understanding this new environment and the physical processes at work will identify acoustically-relevant environmental factors that are critical to successful future deployment of assets in the Arctic.

Our objective was to use unmanned mobile sources and other sensors in this ice-covered environment to collect 3D (depth, range, azimuth) acoustic propagation information that would not otherwise be feasibly attained with either manned or fixed-position assets. Students are using these data with ancillary oceanographic data to investigate issues that have direct impact on acoustic propagation characteristics including changes in (1) under-ice roughness (first year ice vs multi-year ice), (2) under-ice thermohaline structure, (3) ice content and structure, and (4) marginal ice zone dynamics.

Use of EMATTs as a research tool in ICEX-16 will pioneer the way for use of other more sophisticated mobile sources such as our modified REMUS-100 mobile source currently in development that can carry complementary environmental sensor packages to collect data in extreme environments.

Notes:

Profs Joseph T. Klamo & Young W. Kwon
NPS Systems Engineering and Mechanical & Aeospace Engineering Departments

Title: Unsteady loads of UUV during near surface operation

Abstract:
For many tactical mission operations in littoral waters, such as intelligence, surveillance, and reconnaissance (ISR) and mine clearance, an unmanned underwater vehicle (UUV) must operate near the surface of a seaway. Furthermore, near surface operation will always occur during UUV launch and recovery. This near surface operational requirement presents a problem however since each passing wave subjects a submerged vehicle to potentially large unsteady loads that tend to pull it up toward the surface. This situation is exacerbated by the fact that UUVs are considerably smaller than fleet assets so even fairly mild seaways can produce relatively severe unsteady loads. Currently, the physics governing near surface unsteady load generation is poorly understood and consequently not well predicted by existing numeric simulations. As a result, the control algorithms driving the maneuvering performance of a UUV may be inadequate to deal with these loads. This could greatly limit the operational effectiveness of the UUV and potentially lead to vehicle survivability issues. In a worst case scenario, the loads could cause the UUV to broach the surface, exposing its position to the enemy. This would compromise any covert mission and potentially result in the loss of the UUV. In order to eliminate this knowledge gap and allow for better UUV maneuvering performance, we propose to experimentally and numerically investigate unsteady loading on a UUV operating near the surface. The experimental investigation would involve a series of tow tank tests using a generic UUV shape to identify dominant parameters that control the severity of the loading. The wave field parameters to explore include the wave length and height as well as wave heading relative to the vehicle. The vehicle parameters to study include depth, speed, and geometry. Exploring these parameters and their effect on the severity of the unsteady loads will enable an understanding of the governing physics necessary to make more accurate load predictions. One numeric aspect of the investigation would involve quantifying the fidelity of numerous currently available potential flow codes to assess their potential usefulness for load predictions by simulating our test runs within the codes and comparing their predicted loads to our experimentally measured ones. Another aspect of the numeric investigation would involve the creation of simple numeric models that contain only the dominant parameters, guided by the experimental results, for use in control algorithms. The outcomes of this research effort are a better understanding of the dominant parameters controlling unsteady loading during near surface operation and improved numeric tools to help control algorithms compensate for these unsteady loads during those operational conditions.

Notes:

Dr Preetha Thulasiraman
Electrical & Computer Engineering Department

Title: Evaluation of Security Algorithms in Cyber Defense of UAV Swarm Communications

Abstract:
The advances made in swarm communications research both at NPS and at other institutions has exposed a major gap: the lack of basic communications security. This stems from various factors, including cost and how UAV performance is affected by computationally expensive data encryption and authentication computations. However, the inability to solve the security problem has and will continue to have severe consequences for swarm deployment. In the last several years, researchers have studied the various cyber security threats that UAV swarms face. These threats have been identified, along with extensive risk assessments. While there is a consensus in the research community that UAV swarms are vulnerable to cyber security attacks, there has been little movement in identifying appropriate algorithms to facilitate a security architecture for UAV swarm communications. Communications security is required between individual UAVs and between a UAV and the ground control station. This talk focuses on the implementation of security algorithms for UAV to UAV data transfer. We use the NPS ARSENL Lab UAV swarm as the model on which various encryption and authentication algorithms are implemented and tested. In this talk, we highlight the security threats that affect UAV communications data hijacking, and data interception. The security architecture we are developing is meant to thwart these threat models. We discuss the implementation of three different encryption and authentication algorithms and test them for execution time using varying key size and varying message size. All three of these parameters affect UAV communications delay. The three encryption and authentication algorithms are either sanctioned by the NSA for SECRET or TOP SECRET communications or the National Institute of Standards and Technology (NIST). To establish a baseline, we first implement these algorithms in a simulation platform, known as NS-3. The simulation setup and the preliminary results will be shown and discussed. We will also highlight our current efforts which include repeating these experiments on the existing UAV hardware and quantifying the effects of the security algorithms on channel saturation, computational resources, and the bottleneck number of UAVs that can be flown without significant network performance degradation.

Notes:

Prof Geoffrey Xie
NPS Computer Science Department

Title: Reliable Ad-hoc Communication through Multi-path Data Delivery

Abstract:
A swarm of UAVs depends on reliable group data communication in order to maximize surveillance coverage, concentrate attacks on key targets, and form effective defensive perimeters. In other words, reliable data transfer within a swarm is a critical enabler for the swarm's combat effectiveness.

Traditional transport and application layer protocols (TCP, UDP, HTTP/HTTPS, SSH, etc.) use a single network data path ((i.e., a single sequence of nodes) at a time to reach each destination. As such they may suffer from high rate data loss rate and low throughput when the network topology changes frequently and abruptly, typical of swarm operational environments. In this project, we aim to remedy this situation by leveraging the emerging technology of multi-path (MP) data transport methodology which can deliver data to a destination over multiple data paths simultaneously. The MP-TCP standard and related MP-UDP proposals are able to not only spread different amounts of data among multiple paths, but also adjust the spread dynamically according to the measured quality of each path. This fits perfectly with a swarm environment, where UAVs move around, resulting in unstable data paths.

Major challenges remain in order to adapt MP-TCP and MP-UDP to a swarm network as each node typically has one network interface and needs to contend with surrounding nodes for limited transmission channels. To address these challenges we will develop a distributed coordination scheme to allocate the channels efficiently to support MP-TCP and MP-UDP, and ultimately, increase data throughput among UAVs.

Notes:

Dr Don Brutzman
NPS Information Sciences Department/Undersea Warfare

Title: RoboData Archive for JIFX/CRUSER Unmanned System Experimentation

Abstract:

NPS performs many experiments with unmanned systems but few projects are able record results in a reusable way. This presentation describes efforts to establish NPS data-collection capabilities for a wide variety of unmanned system experiments. A design-based approach can support NPS course and thesis work for students and faculty. Utilizing open assets in a repeatable, sustainable way can build an institutional archive of worthy examples that is easy to adopt.

Multiple goals motivate this project to support multiple stakeholders at NPS. Foremost among them is to provide long-term data storage for any unmanned system experiment conducted at NPS. Web access can enable simple data upload and retrieval, data analysis, plots and visualization. Utilizing open-source software and open standards for low cost, unencumbered archivability. Rather than creating some specialty project, we are reaching out to establish an institutional strategy to support long-term NPS missions of graduate education and research.

To achieve these goals, we are adapting a proven operational system to meet NPS needs. The Spatio-Temporal Oceanographic Query System (STOQS) from Monterey Bay Aquarium Research Institute (MBARI) is an open-source data server that provides comprehensive tools for archiving, analyzing and visualizing data from a wide range of scientific missions. Fully open and extendable, STOQS includes an effective query interface, Web-based plots, dataset retrieval, and playback for scientific visualization using the X3D Graphics International Standard. Community participation and shared version control means that progress always rachets forward, never back. Examples are viewable at http://www.stoqs.org

Although robots may differ greatly, collected data has many similarities. Primary data types of interest include the following.

a. Track and sensor data. Most unmanned-system data consists of numeric arrays. Practically universal are time stamps, location, posture (e.g. roll pitch yaw), and (sometimes) velocities. Typically this initial track data is then followed by sensor values of interest.

b. Imagery and video. Special file and server handling is needed for these often-large assets. Currently MBARI maintains multiple systems for photographic and video data; this area requires special attention to do well.

c. Logs and notes. Operator narratives and system-produced logs describe goals, successes, problems and outcomes.

d. Common denominator: metadata. Consistent information about each mission data set (date/time, location, supervisor, key words, etc.) is crucial for search and retrieval. Unit types are often needed for data interpretation. Scientifically correct metadata terms can specifically identify data types for sensor values being measured. References and cross-reference links can connect datasets as part of a larger corpus of work.

e. Metrics. Assessment of effectiveness works on two levels: robotic-system operators producing data, and researchers/analysts/partners/public using the data.

f. Organizing principles. The pursuit of "Big Data" payoffs such as queries, discovery and mashups becomes very difficult if datasets themselves are not structured or consistent. Providing exemplars for both creation and regularization of sensor-driven data collections encourages useful practices.

Current plans include preparing support for early adopters at JIFX next month.

LT Joseph Testa, USN
NPS Mechanical & Aeospace Engineering Student

Title: Vision-Based Relative Navigation of Multicopter UAV in Maritime Interdiction Operation

Abstract:
The project aims to develop and integrate a prototype multicopter UAV with a vision-based control algorithm to enable relative position hold capability. The resulting solution will enable autonomous operation of a UAV with respect to another visually detectable object without use of GPS receiver or when GPS signal is not available. Increased robustness of navigating a robot in a GPS-denied environment is a desired feature in many real-life applications including the Visit, Board, Search, and Seizure (VBSS) operations. While autonomously maintaining UAV's relative position with respect to a target, the onboard system will also provide video coverage of "blind spots" and audio relays between the boarding team and the mother-ship.

Technical objectives include the development of a flight control system and its implementation onboard a quadcopter UAV capable of 30-40 minutes of autonomous flight. The quadcopter UAV could replace man-piloted helicopters in providing visual over watch during VBSS boardings. It is expected that not only the safety of personnel will be increased but also the cost of operation will be significantly less. In the case of boarding a non-hostile target, GPS-based navigation will be the main mode of autonomous UAV operation with the vision-based system providing better response time to changing conditions. In the case of hostile operation or in the inclement weather (fog, dense clouds) when GPS system performance is degraded, the vision-based system (EO or IR based) will provide robust functionality of relative position hold thus increasing operational efficiency of the system. The envisioned concept of VBSS operation includes a number of multicopter UAVs that will be deployed from the mother-ship. While the cooperative operation of multiple UAVs is outside the scope of this particular thesis, the capability proposed for the development here is the fundamental building block of future cooperative missions.

The technical presentation will start with an overview of the state of the art in the area of vision-based relative navigation for small inexpensive multicopter UAVs. Then it presents an initial practical evaluation of enabling technologies ranging from the choice of multicopter hardware and vision processing algorithms. The discussion will focus on significant exploitation of advances of MatLab/Simulink based environment and the tight integration of the developed algorithms with ROS infrastructure. On the experimental side, the envisioned approach will rely on the capabilities of VICON motion capture system that enables true verification of the prototypes. The presentation culminates with the hardware-software architecture that explicitly presents the development and integration steps.

Notes:

Xiaoping Yun/James Calusdian
NPS Electrical & Computer Engineering Department

Title: MATLAB Interface for the P3-DX Mobile Robot

Abstract:
At the 2015 CRUSER Tech Con, we presented our work for a MATLAB-based interface for the P3-DX mobile robot. The P3-DX, as well as the entire series of Pioneer robots from Mobile Robots, Inc. is a popular land-based robot used in research and education. MATLAB is a popular programming environment widely used in science and engineering. Our work up to this point has been to develop this MATLAB-based interface specifically designed for use with the P3-DX robot. Students enrolled in the course EC4310, Introduction to Robotics, have found the interface very easy to use and have successfully developed their own robot applications. This is largely due to the fact that many engineering students are exposed to MATLAB early on in their academic program at NPS. Students in both ECE and MAE use MATLAB to complete class projects and homework assignments in many other engineering courses outside of robotics. This interface leverages their prior experience using MATLAB to make it easy and fun for students to explore the field of robotics.

In this TechCon for 2016, we would like to present some additional work we have conducted to further test and develop the MATLAB interface. The question of timing performance has persisted due to the fact that MATLAB is generally not considered suitable for real-time applications. However, using MATLAB's built-in timing functions we have been able to demonstrate that for the case of the P3-DX and related family of robots, the timing constraints are mitigated with the performance of today's readily-available desktop computers. We will present data from tests we have conducted to quantify the timing performance of the interface.

Another feature we have recently introduced into our MATLAB interface is the availability of high·resolution scanning laser data. Using functions available within MATLAB to enable network communications, data from a Hokuyo UTM-30LX scanning laser, which has been mounted on the robot, is available within the MATLAB workspace. A user-friendly set of functions dedicated to the scanning laser have been developed to provide additional functionality for the interface.

Notes:

Dr Claire Walton, Prof Isaac Kaminer
NPS Mechanical and Aerospace Engineering Department

Title: Optimal Sensor Deployment and Information Gathering Using UxSs

Abstract:
This talk discusses the challenge of optimally utilizing modern UxS capabilities in tasks of Intelligence, Surveillance, and Reconnaissance (ISR). These capabilities include multi-vehicle deployment (possibly in high numbers) and heterogeneous vehicle dynamics and ISR payloads.

Our previous Cruser-funded work has developed tools for UxS defense strategies. These tools have provided a framework for quantifying combat impact and cost based on heterogeneous equipment capabilities and optimizing motion plans in combat situations with rapid weapon fire, multiple agents, and attacker uncertainty characterized by uncertain parameters. Subsequently, we have also worked on incorporating aggressive information-gathering maneavuers and updated intel into defense plans, paving the way for the integration of ISR with active defense.

Our proposal moving forward is to focus on the challenge of optimality on regards to the utilization of ISR payloads. This challenge raises questions of theory--what are the metrics for optimization? (aggregate information, impact-oriented information? risk-mitigation intel?); and questions of computation--how can we incorporate continuous ISR updates into real-time defense planning? The presentation will elaborate on these questions and our proposed approaches for addressing them.

Notes:

Prof Richard Christopher Olsen/Mr. Jeremy Metcalf
NPS Physics Department, Remote Sensing Center

Title: Photogrammetric Point Cloud Fusion Using UAV Collected Thermal Imagery

Abstract:
Remote Sensing data present fundamental challenges in use for intelligence purposes. The data volume is large, almost defining the term "big data". Autonomous processing is difficult, and analysis of imagery largely requires significant human interaction. The primary goal is generally change detection in either the short or long term (day-to-day up to decade-to-decade). Multiple modalities make the process of analysis even more challenging. In particular, extracting results from combinations of panchromatic data, spectral imaging data, synthetic aperture radar (SAR) data, and now light detection and ranging (LiDAR) data presents a problem with few obvious solutions.

The primary issue with bringing multiple observations together, and in particular multiple modalities, is that these data are generally processed into two-dimensional (2D) representations, and then analyzed. This makes the merger of optical and SAR imagery particularly difficult, but really any set of images with varying perspective presents the same problem. The solution is simple enough: address the data in three-dimensions (3D). Technology to extract 3D point clouds from EO data, SAR data, and thermal imaging systems exists now, and can be used to resolve the problem of sensor fusion and change detection.

In recent years, an increasingly wide range of software solutions combining photogrammetry and computer vision have emerged enabling rapid production of 3D content using imagery collected from both metric and non-metric cameras. This emergence is largely due to advancements in GPU parallel processing and the introduction of semi-global matching. Current commercial and open source software are capable of determining image depth at the level of individual pixels, producing "dense" point clouds. Given the availability of high resolution visible to NIR wavelength cameras, photogrammetric point cloud processing has almost exclusively performed on multispectral imagery. Because thermal cameras have much lower resolutions than modern visible cameras, the inclusion of thermal imagery in photogrammetry is often limited to fusion with higher resolution sources.

The proposed effort is to generate photogrammetric 3D temperature models for purposes of sensor fusion by acquiring thermal image data sets using a UAV and a small LWIR (microbolometer) thermal camera. The Remote Sensing Center has been studying the feasibility of photogrammetrically deriving 3D models from terrestrial high resolution oblique thermal imagery directly and the initial results indicate that photogrammetric 3D temperature models can be created from both daytime and nighttime collections.

Notes:

Prof Emil Kartalov
NPS Physics Department

Title: Microfluidic System for Sample Collection by Air Drones for Biohazard Defense and Remote Monitoring of Epidemics

Abstract:
Introduction. Modern communications have made the world a progressively smaller yet more complex and dangerous place. Flash epidemics in remote areas on the other side of the globe can be rapidly brought home by high-intensity air travel and mass migrations. Political instabilities and rogue regimes make WMD attacks (including chemical and biological ones) a distinct possibility. In such an environment, blindly sending boots on the ground into potentially affected areas can lead to unnecessary loss of life among military and civilian personnel.

Innovation. Over the past 10 years, we have developed a series of microfluidic devices and techniques for biomedical diagnostics. We have also patented several such devices including a microfluidic aerosol collector for isolating and concentrating airborne pathogens. We propose to develop the patented system into a practical device, sufficiently light and compact to be carried on an air drone. In one embodiment, once the sample is collected, the drone can return to base, where the sample is removed and processed by the appropriate biotech, such as DNA/RNA extraction and purification and PCR analysis for identification and quantification. In a more advanced embodiment, the microfluidic sample collector is integrated with a miniaturized bioanalyzer, for remote automated analysis on the spot. As far as we know, neither capability has been developed yet, pointing to the high innovation and transformative utility of the proposed system.

Impact. Both proposed embodiments would significantly diminish the need for boots on the ground as well as critically increase the speed, coverage, and affordability of large-area biohazard defense and monitoring. The collect-only embodiment would be the closer and simpler goal, but it would already offer all of the above benefits. The collect-and-analyze embodiment will speed up the sample-to-answer chain, as we would not have to wait for the drone to come back. It also allows for longer continuous operation as the drone can consecutively activate a batch of identical devices as it moves from one region to another. Finally, it would avoid the need for returning the sample to base, thereby completely eliminating the chance of cross-contamination or exposure of home base personnel. Both embodiments heavily draw on the strong synergy of the available air drone technology and the small size and weight of microfluidics-based biomedical diagnostic capabilities. Furthermore, the high air speed of the drone makes it trivial and fast to sample a very large volume of air, thereby significantly improving the chances of detection compared to conventional methods.

Scope of the Proposed Project. Within the scope of the proposed project we would:
1. Build and further develop the sample collector chip based on our patents and experience
2. Test the collector with harmless analytes in aerosol preps to debug and produce proof of principle
3. Integrate the collector with a typical low-cost drone, e.g. an RC helicopter, to test atmospheric collection of dispersed harmless analytes in aerosol phase
4. Produce a final report with the device specs and recommendations for further research with special agents and full-scale air drones.

Prof Emil Kartalov
NPS Physics Department

Title: Conceptualization Study of Unmanned Remote-Crewed Armored Fighting Vehicles

Abstract:
Introduction. While armor, weaponry, sensors, computation, and communications have evolved significantly since WWII, the basic formula of 3-5 crew in armored fighting vehicles has remained unchanged. Yet, the crew compartment together with the human interface and life support equipment take about HALF the internal space, contributing heavily to the total weight, complexity, cost, and required protection. This discrepancy suggests a transformative solution.

Innovation. We hypothesize that modern communications, robotics, and sensors make it already possible to switch to remote-crewed armored vehicles (RCAVs), without loss of tactical value and with major gain of combat capability. There already are troubling examples, including in armies of potential adversaries, of crewless turrets, remote-controlled weapons, and all-around sensors! From our viewpoint, these are intermediate, crossover designs, clearly pointing to an inevitable forthcoming wave of remote-crew drone technology taking over ground combat, just as it has taken over air reconnaissance and is permeating air-to-ground combat. Our proposal is aimed at putting the groundwork towards RCAVs, since they are a clear means to maintain decisive superiority on the ground.

Impact. Switching to RCAVs will lead to a reduction of total weight by one-third to HALF, and an accompanying reduction in unit price, maintenance costs, etc. Furthermore, RCAV offers a unique opportunity to fundamentally rethink both the vehicle design and the command-and-control structure of an armored section or even platoon. For example, remote crew means it would be trivial to add specialized crew, such as extra gunners, systems tech, EM/ECM officer, and (critically!) observers, without the physical restrictions of having them fit within the vehicle. Also, unlimited computational capability is sourced out of the vehicle and into the remote command center, where virtual reality (VR) network can be built to encompass all crew members and sensory outputs of the RCAVs in the section and even the platoon. The result would be a VR combat space (VRCS) with unparalleled detail and capabilities, limited only by the computational power at the command center, the data transfer rate between the center and the RCAVs, and the sensor suite installed on the RCAVs. Once developed, these capabilities can also be used as a launch pad for replacing platoons of infantrymen in the field with their mechanical avatars, while the infantrymen become their controllers plugged in the same VRCS at the command center.

Scope of the Proposed Project. Clearly what we are talking about is a very large undertaking when built up to full scale. So, within the scope of the proposed project we would:
1. Establish a collaborative network of researchers and experts for the task
2. Study the current state of the suite of technologies that need to be integrated
3. Generate design ideas based on mission parameters, field experience, and current technologies
4. Identify technological bottlenecks and brainstorm ideas to circumvent or overcome them
5. As a final deliverable, produce a detailed report that includes technical and tactical recommendations, and identifies the critical technical and organizational roadblocks that would require focused further research to solve or overcome.

Prof Peter S. Guest
NPS Meteorology Department

Title: Using Quad-rotor UAS to Perform Meteorological Measurements From Ships

Abstract:
In recent years, the use of Miniature Quad-Rotor Unmanned Aerial Systems (MQRUAS) has increased greatly for a wide variety of uses. Relatively inexpensive (< $1500) MQRUAS systems contain GPS, inertial navigation and/or active altimeter features that greatly reduce the skill and training needed for safe and effective operations. With minimal training, a pilot can take-off, perform missions and land MQRUAS without the need for landing strips or catching devices such as nets or snag lines. A recently-developed use of MQRUAS, pioneered by the author with support from CRUSER, is for performing measurements of the lower atmosphere. With a series of experiments at Camp Roberts CA, the author, colleagues, and students demonstrated that the InstantEye MQRUAS, with a radiosonde (a meteorological instrument usually used on weather balloons to measure temperature, humidity and pressure) attached, could provide data with a sufficient accuracy to be useful for input into weather prediction and electromagnetic propagation operational models. These tests also demonstrated that someone without extensive technical or operational experience in aviation (the author) could quickly develop proficiency in performing meteorological missions with MQRUAS. The utility of using MQRUAS for meteorology research and operationally support was further demonstrated with a series of flights in the Arctic Ocean from an ice breaker and adjacent ice floes in the fall of 2015.

An ultimate goal of this research is to facilitate the use of MQRUAS or similar automated robot systems by the US Navy METOC (Meteorology and Oceanography) community. The US Navy recently abandoned its upper air weather balloon measurement program and as a result there is serious gap in the Navy's ability to characterize the Battlespace Environment in real time, in particular the effect of the atmosphere on systems that use electromagnetic radiation such as radar, radios, jamming and electronic surveillance measures. The research by the author is attempting to demonstrate that MQRUAS outfitted with meteorological sensors could be used on a routine and special mission basis by the fleet to deliver crucial environmental information in a cost-effective manner. The future focus of this research will be on marine operations: launching and recovering instrumented MQRUAS from ships and smaller vessels. During this summer, a series of three day cruises will be performed just outside the Monterey Bay in international airspace on the R/V John H. Martin, a small (56 foot) research vessel operated by Moss Landing Marine Laboratories. The InstantEye MQRUAS will be launched from the vessel and perform several profiles each flight before returning to the ship. This presentation will provide details on these planned flight operations and future proposed uses of MQRUAS systems for meteorological use.

Notes:

Prof Susan M. Sanchez
NPS Operations Research Department

Title: Closing Capability Gaps: Data Farming Methods for New Concept Exploration in the CRUSER Community

Abstract:
Computer experimentation is integral to modern scientific research, national defense, and in public policy debates. These computer models tend to be extremely complex, with thousands of factors and many sources of uncertainty. Data farming helps researchers understand the impact of those factors and their intricate interactions on model outcomes. Data farming is the process of using computational experiments to grow data, which can then be analyzed using statistical and visualization techniques to obtain insight into complex systems. Effective data farming draws on state-of-the-art technologies including design and analysis of experiments, high-performance computing, and data mining.

NPS's Simulation Experiments & Efficient Designs (SEED) Center for Data Farming is internationally recognized for its advancement of both the theory and the practice of large-scale simulation experiments. Many SEED Center students have already applied design of experiments (DOE) techniques on agent-based or discrete-event simulation models to explore the potential use of unmanned vehicles in operational environments, with great success. The students have come from the Army, Navy, Marines, and Air Force, as well as international allies. They have investigated unmanned vehicles of many types—aerial, ground, surface, and underwater—for missions related to reconnaissance and surveillance, IED detection, mine detection, border security, asset protection, casualty evacuation, humanitarian logistics, and more. We will highlight some of the methodological results (improved ways of conducting data farming studies), as well as recent and current student thesis topics that involve unmanned vehicles.

Those seeking more in-depth exposure to the data farming concepts and approach are encouraged to take advantage of other opportunities. The next event is a half-day tutorial on data farming that will be held on the Monday of the OCEANS16 in Monterey. Examples in this tutorial will involve simulation models that incorporate the use of unmanned vehicles in operations.

Notes:

Mr Sean Kragelund, Dr Claire Walton, Prof Isaac Kaminer
NPS Mechanical and Aerospace Engineering Department

Title: Sonar Detection Mission Planning Tool for Autonomous Vehicle Teams

Abstract:
The Navy has invested heavily in the development of sonar systems and unmanned platforms for mine countermeasures (MCM).). The adoption of UxVs (i.e., unmanned underwater or surface vehicles) as highly mobile sonar platforms has greatly increased search options, however operational plans for UxV-based search still lag behind the ultimate potential of this hardware. Despite their potential for advanced automation, UxVs are typically being deployed in historically standard, geometric search patterns, such as the "lawn mower" pattern. These methods, although functional, are fundamentally holdovers from the era before rapid computation and automation. They are conservative solutions, generated by past needs for computational simplicity in vehicle modeling and easy programming/execution of path plans.

Our proposal is to develop a mission planning tool for UxV search deployment which incorporates modern computational advances to provide greater utility for the MCM community. Specifically, we propose to integrate a key development of the last decade: Computational Optimal Search. The deployment of search effort has been a topic of Naval Operations Research since WWII, but optimal solutions—based on realistic sensor models and nonlinear vehicle dynamics—were not possible until recently. Thanks to research out of NPS in the last five years, however, this is no longer a barrier. We can now numerically compute vehicle trajectories which optimize detection probabilities given multiple, cooperative UxVs, and detailed heterogeneous vehicle dynamics and sensor characteristics.

We propose to refine this computational framework into a tool of practical application to MCM. Specifically, NPS has developed sonar detection models for the Autonomous Topographic Large-Area Survey (ATLAS) forward-looking sonar and the Marine Sonic side-scan sonar carried on the Mk 18 Mod 2 Kingfish and Mk 18 Mod 1 Swordfish UUVs, respectively. The resulting optimal solutions facilitate rapid evaluation of different vehicle and sensor combinations for conducting the mine detection and reacquisition/identification phases of an MCM operation. Similarly, by incorporating more accurate, physics-based models of sonar performance and vehicle motion, as well as bathymetry maps and Bayesian target priors, Computational Optimal Search can be a powerful tool for both path planning and pre-operation analysis. This would allow mission planners to analyze a wealth of trade-offs with respect to the number, type, and sensor load-out of different unmanned platforms to employ in order to meet a given mission risk threshold within available time constraints.

Notes:

Dr. Don Brutzman
NPS Information Sciences Department/Undersea Warfare

Title: QR and DFL Optical Communications for Network Optional Warfare (NOW)

Abstract:
Naval forces do not have to be engaged in constant centralized communication. Deployed Navy vessels have demonstrated independence of action within coordinated operations for hundreds of years. Littoral operations, unmanned systems, and single-purpose ships pose a growing set of naval challenges and opportunities. Network-optional warfare (NOW) can be achieved through efficient communications, signaling stealth, and deliberate tactical messaging.

The surface fleet can reduce detectability through Agile EMCON and avoiding radio transmissions, which in turn reduces vulnerability and raises the potential for tactical surprise. Optical signaling is difficult for an opponent to intercept, but has range limited to line-of-sight (LOS) distances for current interactions. Nevertheless, flashing-light signals sent ship-to-aircraft then relayed aircraft-to-ship via video can provide an Over The Horizon (OTH) messaging capability under EMCON conditions. Repeated testing during all weather and day/night conditions can also provide useful test data regarding visibility and ranging. Message tests during afloat operations can help naval units regain familiarity with a historic channel for covert signaling.

Flashing-light messaging is somewhat of a “lost art” due to personnel constraints and the always on conveniences of Network Centric Warfare. However, time-consuming training to achieve Morse code proficiency is not required when video is used to record optical messages. At-sea test results using deployed hardware can prepare the path for future deployment of digital optical signaling developments, which are already under way using Quick Reaction (QR) Code Streaming and Digital Flashing Light (DFL). Stabilized video recording by manned or unmanned aircraft can further extend such secure communications from “line of sight” to “line of flight” without risk of electromagnetic (EM) interception or network-centric cyber vulnerabilities. LED signalling provides further opportunities for deployment.

This talk will demonstrate CRUSER-produced open-source software for QR signaling that has been selected for continued development next year as part of the Naval Research Program (NRP). Multiple projects suitable for student theses will be presented, participation is welcome.

Notes:

CRUSER's Vision

CRUSER provides the foundation for a community of interest and a collaborative environment for the advancement of unmanned systems education and research endeavors across the Navy, Marine Corps and Department of Defense. CRUSER spans the research, education, and experimentation efforts in unmanned systems and robotics at NPS and across the naval enterprise.

The CRUSER community of interest welcomes researchers from all disciplines; if you are interested in robotics and unmanned systems we're interested in you. We explore ethics, policy, human capital resource requirements, cultural and societal issues associated with robotics and unmanned systems in addition to the technical aspects such as work on extended battery life, controls, sensors, design and architectures. Whether it's exploration of new concepts or new ways to employ existing platforms the CRUSER community welcomes you.

What is CRUSER?

CRUSER is a SECNAV initiative to build a community of interest on the application of unmanned systems in military and naval operations.

Why should I join?

- Enjoy the camaraderie of a focused community of interest
- Seize the opportunity to expand your list of contacts
- Share your research progress and ideas through our monthly newsletter
- Participate in Concept Generation
- Participate in Unmanned Systems/Robotics experimentation
- Learn about your colleagues discoveries at the monthly CRUSER meetings – available via VTC and dial-in

How do I join?

- Sign-up on our website
- Send us your name, e-mail, org name, and title to cruser@nps.edu

For more information on CRUSER and upcoming events visit: http://CRUSER.nps.edu

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