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CRUSER • NEWS

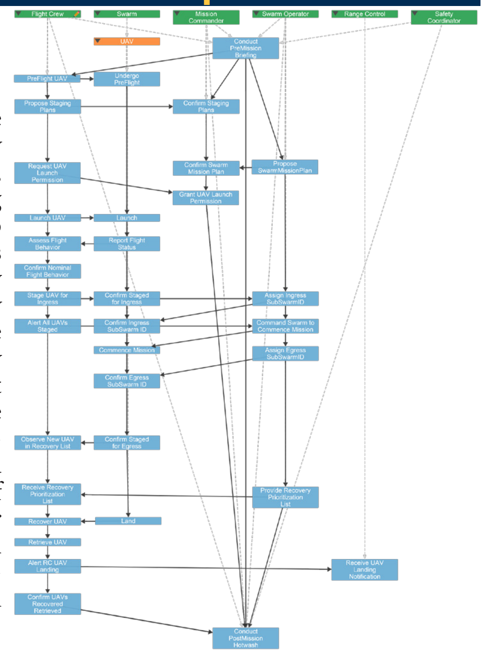
Consortium for Robotics and Unmanned Systems Education and Research

From Technical to Ethical...From Concept Generation to Experimentation

Contents

Got Monterey Phoenix?

by Prof Kristin Giammarco, kmgiamma@nps.edu



Some most exciting innovations are being found at the intersection of different disciplines. With transdisciplinary systems thinking, we view a problem space horizontally, soaking in its breadth; then move vertically by abstracting up or refining down, depending on the detail needed to solve a problem of interest. Put anyone who thinks this way in a domain or discipline other than one they grew up in, and something interesting tends to happen. They instinctively hone in on possible connections between the new domain-specific information and the knowledge they already have from their home discipline, an effort that sometimes results in the recognition of a pattern. These patterns result in new potential applications of general principles, as well as new potential generalizations of detailed implementations. Climbing up and down this ladder of abstraction and refinement in modeling systems and their environment is the mental workout behind a new approach to design; an approach that illuminates dark corners containing behaviors that might otherwise not be exposed until later in the lifecycle.

In the Spring of 2015, the Monterey Phoenix (MP) approach to system behavior and process modeling transitioned from an experimental laboratory implementation setting to a user-friendly beta implementation available publicly at http://firebird.nps.edu/. Nicknamed MP Firebird, this tool is powered by an event trace generator created by MP architect Mikhail Auguston at the NPS Computer Sciences Department, and was made easy for beginners and practitioners to use with a friendly GUI developed by the NPS Center for Educational Design, Development, and Distribution (CED3). It is the first system and process behavior modeling tool of its kind, specializing in leveraging the small scope hypothesis proposed by Daniel Jackson at MIT, which states that most errors can be exposed on small examples.

MP Firebird is a research product that spans at least two disciplines: software engineering and systems engineering. These disciplines have lent their own unique perspectives to fuel MP's evolution. MP employs a high-level, domain-independent language that enables transdisciplinary conversations where not everyone need be an expert in the vernacular of an unfamiliar domain. Instead, conversations take place at an architectural level to capture the logic for the behavior of a system and that of its environment. Stakeholders can then reason about the various possible combinations of behaviors with automated tools, like MP Firebird. Automatically generated event traces are inspected for undesired behaviors spelling trouble for the design, so that constraints can be added to prevent or minimize them. This reasoning about a system's architecture strengthens the bridge between stakeholder needs and the detailed design. An iterative process of problem understanding and requirements discovery is undertaken before making design decisions that are difficult or very costly to undo later as originally poorly understood needs come to light.

MP Firebird was made possible with the sponsorship of CRUSER and was developed in support of UAV swarm failsafe research and analysis being conducted in FY15. The tool is currently being used to expose ambiguity and incompleteness in UAV CONOPs, and work is underway to insert system-level failure modes in search of compound, swarm-level failure modes. Future work includes the modeling and verification of robotic system architectures by generating an exhaustive set of use cases for understanding the requirements and supporting automated testing of implementation.

MP supplements and enhances abilities of traditional process and system modeling frameworks and notations, like SysML, DoDAF, and BPMN. To try MP on a problem of interest to you, visit the MP wiki at https://wiki.nps.edu/display/MP/

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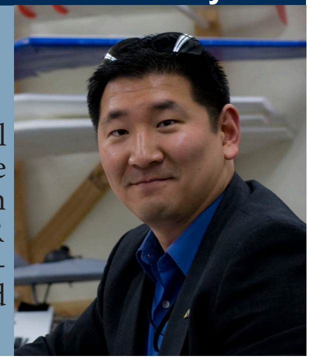
Director's Corner

Tim Chung, CRUSER Deputy Director



The challenges of robotics and unmanned systems extend well beyond the technological hurdles of systems integration of autonomy, perception, mobility, and communication. The complexity of both the systems and the uncertainty of the environments they operate in pose significant opportunities for innovation, as explored in this month's issue of CRUSER News. From formal methods to secure command and control to under-ice UUV operations, these capabilities truly expand the frontiers of how and where robotics and unmanned systems can operate!

Secure Wireless Command & Control: The Key to the Reliable Implementation of Unmanned Systems

by Phil Linker, FreeWave Technologies, klambert@freewave.com

Unmanned vehicles are at the forefront of an evolution. After decades of serving mission-critical applications in government and defense, unmanned systems have begun to migrate into the public safety, research, and commercialized marketplaces. The robust and secure infrastructure necessary for the eventual proliferation of Unmanned Aerial Systems (UAS) in the National Airspace System (NAS) is slowly being realized.

Safety is a top priority of the FAA for the operation of UAS, particularly as it relates to secure and reliable Command and Control (C2) links and sense and avoid tactics. Therefore, the wireless communications link in which the unmanned system operates plays an essential role in meeting security requirements, and with a reliable and secure CNPC link, a UAS can be trusted to operate effectively. Additionally, unmanned systems with unsecure and unproven C2 links are vulnerable to failure and even hijacking.

There are a number of secure wireless data communications solutions available that enable reliable C2 links and have been trusted by the government and defense industry for years. Additionally, some solution providers offer multiple frequencies for C2 links providing unmanned systems manufacturers with a portfolio of options to deploy. Here are key considerations for secure C2 links that need to be integrated as part of the overall unmanned system:

Access Control Methods by Authentication, Authorization and Accounting

One option that some unmanned systems operators have employed is the use of proprietary wireless data radio communication systems and devices (especially when they offer many "knobs" and configuration options to create private, user defined networks). These proprietary solutions can offer a higher degree of security in some scenarios, but as the FAA and the RTCA special committee continue to work, they will be defining new requirements for an open, non-proprietary solution.

Advanced Encryption Standard

In November 2001, FIPS Publication 197 (http://csrc.nist.gov/publications/fips/fips197/fips-197.pdf) announced the Advanced Encryption Standard (AES), a cryptographic algorithm that could be used to protect electronic data. Today, AES is a Federal Government and commercial standard, trusted even by the NSA to protect sensitive information and maintain data privacy.

AES encrypted devices offer a variety of key strength options, including 128, 256 and others. NIST has also defined 5 modes of operation for AES: Cipher Block Chaining, Electronic Code Book, Cipher Feedback, Output Feedback and Counter Mode. It is argued that counter mode is the most secure of the five because it uses a sequence of blocks to encrypt the data and is never repeated.

FIPS Publication 140-2

NIST issued the 140 series of FIPS Publications to identify the key requirements for cryptography modules. FIPS 140-2 validation consists of four clear levels of security, with Level 1 being the lowest and each Level thereafter building upon the next with additional security and/or trusted requirements, all the way up to Level 4. For example, Level 2 adds requirements for checking physical evidence of tampering, as well as role-based user authentication. Level 3 requires physical tampering resistance (further physical qualities making the module itself more protected against attackers attempting to gain access to sensitive information within the module itself) and a stricter identity-based authentication. Level 4 adds even more physical security requirements and requires an even greater robustness to the platform, in order to hold up against environmental attacks.

CRUSER Monthly Meetings
Mon 13 Jul, 1200-1250 (PDT)
Mon 17 Aug, 1200-1250 (PDT)
details at http://CRUSER.nps.edu

Short articles (up to 500 words) for CRUSER News are always welcome submit to: cruser@nps.edu

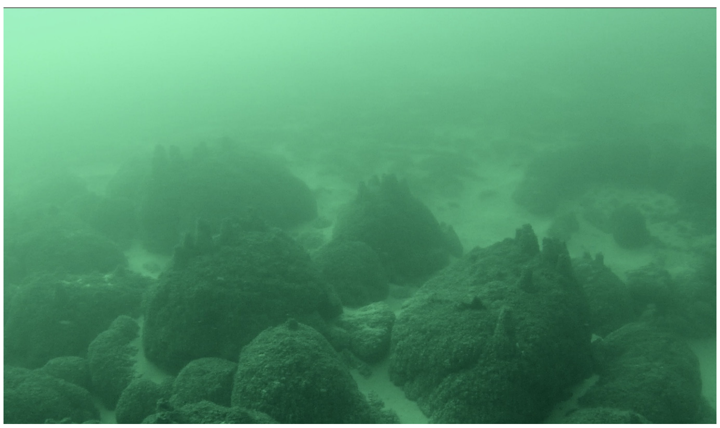
NPS Faculty Battle Extreme Environments to Further AUV Research

by Kenneth A. Stewart, NPS,

Naval Postgraduate School (NPS) Research Associate Professor Douglas Horner and Research Assistant Professor Noel Du Toit recently returned from remote Pavilion Lake, British Columbia where they investigated Autonomous Underwater Vehicle (AUV) operations in extreme, under-ice environments.

"The Navy is very interested in our ability to work under the ice using autonomous vehicles," said Horner. Pavilion Lake is located some 250 kilometers northeast of Vancouver, British Columbia. Its frozen-over waters became a natural laboratory in which Horner, Du Toit and a multi-disciplinary team of colleagues were able to test navigation algorithms developed at the NPS campus in Monterey, Calif. and beyond.

"The lake's bathymetry is incredible. It varies from 60 to four meters depth in less than a 300 meter distance," explained Horner. "It provided a unique opportunity for testing the AUV's ability to collect sensor data while both avoiding potentially hazardous obstacles and building an accurate map." Horner and Du Toit both teach at the NPS Department of Mechanical and Aerospace Engineering (MAE). Horner is co-director at the university's Center for Autonomous Vehicle Research (CAVR) and Du Toit has been participating for several years in NASA's Extreme Environments Mission Operations (NEEMO) program. The researchers also partnered with NPS' Consortium for Robotics and Unmanned Systems Education and Research, or CRUSER, which helped fund the Pavilion Lake experimentation.



While there are many facets to Horner and Du Toit's combined experimentation efforts, at issue are three main capabilities – the development of navigational techniques that allow AUVs to travel without reliance on GPS; the development of adaptive controllers that will enable robust under-ice operations with changing vehicle configurations; and the development and testing of real-time surveying and 3D-mapping capabilities.

Horner and Du Toit also used their time at Pavilion Lake to gain experience conducting under-ice operations in preparation for further research at Lake Untersee, Antarctica later this year and in the Arctic next year. "We are trying to do this in increasingly aggressive environments. We started in Pavilion Lake without ice, and now we have conducted experiments beneath the ice. Next, we intend to conduct experiments in a more challenging lake environment in Antarctica and culminate with AUVs deployed beneath moving sea ice in the Arctic," Horner explained.

According to Du Toit and Horner, under-ice research is increasingly important to the Navy due to the effects of melting polar ice and its implications on geopolitical and economic interests in the region. But before the Navy is able to fully realize the benefits of their work beneath the ice, they must first get the science right. To do that, Horner and Du Toit will have to contend with not only extreme temperatures, and changing currents, but with moving sea ice and the physical effects of varying sea ice densities and compositions.

"All of our sensor measurements have to be integrated in a manner that makes sense mathematically," said Du Toit. "The information comes in from a number of distinct places and has to be combined in a way that captures the relative quality of the information." One of the most important research outcomes that Horner and Du Toit hope to realize from their efforts is the ability to accurately and reliably navigate in a variety of challenging environments – from beneath the ice or in the cluttered littorals, the Navy has begun to navigate in these regions with greater frequency.

"Imagine the vehicle is moving around with a bubble of uncertainty around it. When GPS is available the bubble is small, but when it isn't available or when we don't want the vehicle to surface, the bubble can grow. The bigger the bubble, the less confident we are about its actual location," explained Horner. "We are interested in how terrain and natural underwater features can help us to manage the bubble and keep it to a minimal size."

Using a process known as Terrain Aided Navigation (TAN), Horner and Du Toit are able to estimate their AUVs' positions in relation to a map. "But when you use a map one assumes it is correct even though accurate, high resolution undersea maps are frequently not available," said Horner.

To overcome this challenge, Horner and Du Toit are developing

STUDENT CORNER

Student: LT Bradley R. Turnbaugh, USN

Title: Extending Quad-Rotor UAV Autonomy with Onboard Image Processing

Curriculum: Mechanical and Aerospace Engineering

Link to Completed Thesis: https://calhoun.nps.edu/handle/10945/45265

Abstract: One of the most dynamic technological advances of the last decade is the development of unmanned and autonomous vehicles. For the military, these vehicles represent a safer and more efficient way of fighting wars in aerial, ground, maritime, and underwater domains. Public and private companies have also vigorously researched these vehicles and used them for a wide range of tasks, from search-and-rescue operations to building inspections. Navigating these vehicles typically involves the use of GPS or other external cues to follow a path, detecting for and correcting errors along the way. The purpose of this research is to investigate the feasibility of tracking a ground target using a quadrotor that navigates solely based on relative position to the target. To achieve this goal, the quadrotor, a Quanser Qball-X4, is fitted with a small camera. By processing the camera's image and utilizing pitch, roll, and altitude data from other onboard sensors, a targeting solution can be derived. To track the target, the tracking vehicle defines error as any deviation from the desired angular offset from that target, continuously correcting that error to maintain its desired offset. By using relative position, the tracking vehicle can continue to follow the target using its onboard camera.

techniques to build better maps with incomplete data. The methodology relies upon "optimal spatial estimation" to use available measurements to build maps and subsequently rely upon them to determine their AUV's most likely position. But what happens in the absence of accurate maps and the only terrain feature detectable is the ice itself?

"The eventual goal is to turn this capability "upside-down" and to use sonar and complementary sensors on the underside of the ice at the polar caps to reduce AUV positional uncertainty," said Horner. "Before, we were looking downward at the [ocean floor] topology to match geographical features to a map, but in the arctic we do not have that luxury."

"Your navigational goal is going to determine how you are going to use the map," explained Du Toit. For Du Toit, positional certainty is critical. He is focused upon creating high-fidelity 3D maps that can be used by robotic systems to not only maneuver under austere conditions, but to interact with the environment as well.

Du Toit's work at Pavilion Lake built upon experiments he conducted last year at Florida International University's Aquarius Habitat. There, in collaboration with NASA's Johnson Space Center, Du Toit worked with the NEEMO program to investigate robot-assisted human exploration in challenging environments. He hopes that by enhancing AUV mapping and navigational capabilities, he will be able to improve diver safety by relegating dangerous tasks to AUVs altogether. "The next piece is our ability to interact with the environment, for example to pick up and retrieve things," said Du Toit. Such a capability will provide novel utility to the Navy in support of undersea operations, but requires underlying capabilities such as accurate mapping and precise vehicle control.

But while the development of new navigational and control technologies is the primary focus of Horner and Du Toit's work, the use of AUV's in these austere environments is also presenting them, and a group of astro and marine biologists from NASA Ames Research Center with the opportunity to observe some of the earliest known organisms in existence today. "Pavilion Lake is home to a large population of freshwater microbialite structures that have been studied by NASA and CSA scientists," said Du Toit.

Similar colonies of microbials are known to exist beneath the Antarctic ice covering lake Untersee. "The Antarctic microbial colonies are unique and have been isolated from the rest of the earth's atmosphere since the last ice age," explained Du Toit. Fossils with similar structure point to the existence of microbials as early as 3.45 billion years ago in what was the Earth's earliest biosphere. According to Du Toit, these Antarctic microbial colonies – which only receive sunlight a few months out of the year in a lake permanently covered with three meters of ice – help astrobiologists to identify the conditions under which life may exist elsewhere in the solar system, perhaps even within the enormous salt-water sea recently discovered by NASA beneath the Jovian moon, Ganymede.

http://nps.edu/About/News/NPS-Faculty-Battle-Extreme-Environments-to-Further-AUV-Research.html

Librarian's Corner

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