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Consortium for Robotics and Unmanned Systems Education and Research

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

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A Collaborative Diver Assistant for Underwater Operations

by Dr Noel Du Toit, NPS Faculty, nedutoit@nps.edu, Students: LT Andrew Streenan, and LT Josh Weiss

Diver operations are inherently dangerous. Physiological effects limit dive duration and frequency and necessitate a large support crew, increasing operational costs. These environments tend to be complex and cluttered, and the tasks are complicated, requiring advances in controls, sensing, perception, and communication. The Center for Autonomous Vehicle Research (CAVR) is developing a robotic diver assistant system to provide autonomous support to diver teams, which has the potential to significantly enhance underwater operations. The project is aimed at providing utility to the diver team (e.g., illumination, improved situational awareness, etc.) without burdening the team with vehicle command and control, thereby augmenting the diver team and allowing more effective, efficient, and safer operations. The technology is relevant to several Naval communities, including Undersea Warfare, Naval Special Warfare, Explosive Ordinance Disposal and Salvage Diving.

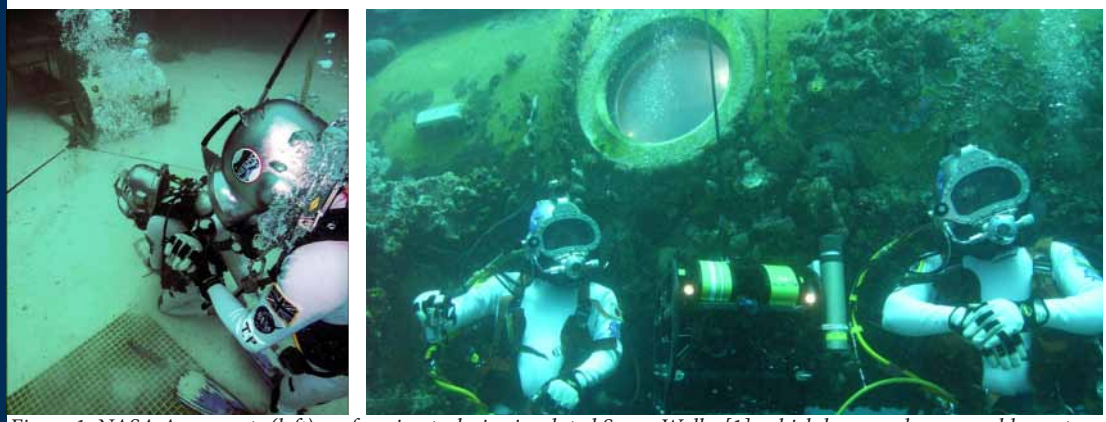

Figure 1: NASA Aquanauts (left) performing tasks in simulated Space Walks [1], which bears a close resemblance to underwater EOD tasks, and (right) posing with the NPS CAVR Tethered Hovering Autonomous Underwater System (THAUS) at the Aquarius Habitat in Key Largo, FL.

Research in the following domains are required to realize the overall objective of a robotic diver assistant: autonomy, collaboration, and decision making; close-range surveying and 3D mapping; human-robot communication and information sharing; precise vehicle control.

The envisioned robotic diver assistant will be a fully autonomous, untethered platform. To facilitate safe operation among human divers and close to the ocean bottom, the platform must have omnidirectional control authority in the horizontal plane, as well as vertical and yaw control. These control requirements differ substantially from traditional AUV platforms, which are designed to travel very efficiently in the forward direction, with very limited lateral control. The SeaBotix vLBV300 ROV [2] satisfies the above requirements and has been modified to enable fully autonomous control, resulting in the Tethered Hovering Autonomous Underwater System (THAUS). Furthermore, the system has been augmented with a Greensea System INS system and Doppler Velocity Log, enabling in-ocean operations.

Figure 2: The SeaBotix vLBV300 ROV [3] platform allows longitudinal, lateral, and vertical motion for the system to overcome surge and currents and operate safely with human divers.

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Director's Corner

Nothing elicits thoughts of summer so much as sub-freezing temperatures, and summer means high school and college interns. High school and college students are already applying for STEM programs and will soon choose from among the leading science and technology projects in the country; we need to ensure that CRUSER programs are on that list. If your research plans align well with mentoring during the summer months I encourage you to submit your name and project to your STEM coordinator (by January 14th) to ensure CRUSER is well represented on the list of choices for the students. I can't think of a better way to spend the summer than inspiring young minds to pursue greater knowledge.

Steve Iatrou, CRUSER Director of Strategic Communication

Behavioral Modeling of Software Intensive System Architectures Using Monterey Phoenix

by Monica Farah-Stapleton, NPS Student, monica.farah-stapleton@dha.mil

Even though engineers and scientists enjoy debating the nuances of definition (e.g. systems, systems-of-systems, environment, emergent behavior), there is a common recognition that the world is comprised of integrated, complex, distributed systems that continually and dynamically adapt to their environments. And there is a need to be able to understand and reason about the behaviors of these systems and environments.

Consider the simple scenario illustrated in Figure 1. A UAV is introduced into an environment of existing systems, to provide network connectivity based on an analysis of mission requirements, link performance, and terrain considerations. The risk associated with introducing a new system into an existing environment can be mitigated by utilizing models that capture the behavior of not only the system, but also the behavior of the environment with which it interacts. Behavioral modeling of system architectures and environments, if done precisely but at an appropriate level of abstraction, can reflect design decisions, provide a framework to reason about those decisions, and then facilitate verifying assertions early enough in the design process to prevent incurring the costs of incorrect implementations. Accurate and complete architectural descriptions and views of complex systems establish a common mental model among stakeholders, helping them to consistently answer groups of questions on technical performance considerations, development schedules, time to deployment, and resourcing, all of which are critical to the overall decision making process.

The Complex Adaptive Systems (CAS) conference (http://complexsystems.mst.edu/) held November 13-15, 2013, in Baltimore, Maryland, offered an opportunity to share information on how to address complexity, focusing on the theme " Emerging Technologies for Evolving Systems: Socio-technical, Cyber and Big Data". The session on Systems Behavior Modeling included presentations on architectural modeling to inform software intensive system-of-systems engineering analyses, emergent behavior prediction, and quantifiable cost estimation. Presentations also introduced Monterey Phoenix

(MP), a behavioral model for system and software architecture specification based on event traces. MP supports architecture composition operations and views, and captures behaviors and interactions between parts of the system and the environment with which it interacts. As an executable architecture model leveraging "lightweight" formal methods and the Small Scope Hypothesis, MP supports automatic generation of behavior examples (Use Cases) for early system architecture analysis, testing, verification, and validation. MP also has powerful interaction abstraction, separating the description of the behavior of the component from the interaction between components. MP can be applied to classes of tasks associated with hierarchical interactions between a system and its environment, an important feature for model reuse and scalability.

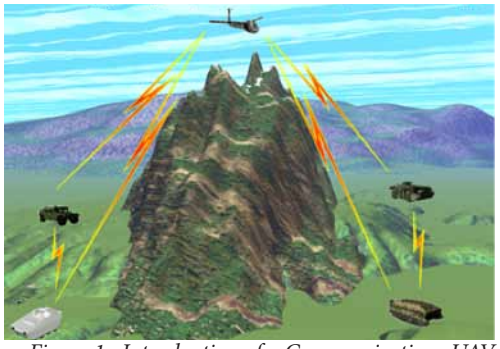

Figure 1. Introduction of a Communications UAV

Additionally, a methodology was introduced during the Systems Behavior Modeling session that utilized MP to inform quantifiable cost estimates (e.g. Function Point analysis) and ultimately project, program, and enterprise level resourcing decisions. Function Point analysis is a measurement practice for sizing software, that requires an understanding of counting scope and application boundaries. MP can be used to unambiguously describe boundaries and interactions of the system, user, and environment. Once boundaries and interactions are identified, the Function Point analysis methodology can be applied: Counting the Data and Transactional Function Types; Determining the Unadjusted FP count and the Value Adjustment Factor; and Calculating the final Adjusted FP Count.

MP is focused on behaviors, interactions, and automated tools for early verification, thereby enhancing and extending the software and systems engineer's toolkit of DoDAF, UML, and SysML to inform technical and resourcing decisions. For additional information on Monterey Phoenix and related work, the reader is invited to contact the author directly and visit :

- http://faculty.nps.edu/maugusto
- http://www.sciencedirect.com/science/article/pii/S1877050913010727
- http://www.sciencedirect.com/science/article/pii/S1877050913010739
- http://modeling.eagle6.com/

Knowledge representation, Logic, and Advanced Programming (KLAP) Laboratory

by Enrico Pontelli, Computer Science Department, New Mexico State University, epontell@cs.nmsu.edu

The Knowledge representation, Logic, and Advanced Programming (KLAP) laboratory at New Mexico State University has been established in 2004. The lab is directed by Dr. Enrico Pontelli and Dr. Son Cao Tran, and has several affiliated researchers and students.

Since its inception, the laboratory focused its research on the theoretical and practical foundations of autonomous agents, with particular emphasis on the development of efficient algorithmic solutions for reasoning in complex domains. Complex domains are characterized by several properties, which are frequently occurring in the deployment of autonomous agents in real-world scenarios. In particular, our focus has been on:

- Agents that have incomplete knowledge of the environment in which they operate, and yet they need to devise a plan of action that is guaranteed to succeed (i.e., conformant planning)
- Agents that operate with actions that might be unreliable and have unpredictable effects (i.e., contingent planning)
- Agents that operate in environments that include several other agents, and need to take advantage of the knowledge (or lack of) of the other agents to achieve an objective. This may include deceiving other agents by providing false information or seeking the help of agents to achieve an objective.

The team at KLAP has developed a number of logical models to describe agent domains and capabilities, and use such formalisms to guide the development of efficient planning algorithms. A notable achievement has been the creation of a class of conformant planners (CpA) that achieved the best performance in the 2008 International Planning Competition.

The research at KLAP has also explored the use of high-performance computing solutions to provide an alternative avenue to speed-up the process of autonomous planning and reasoning. The study explores the use of both traditional parallel platforms (e.g., multi-core processors) as well as the massively parallel architectures provided by modern graphical processing units. The approaches pursued in our research include both traditional schemes to parallelize the research process underling planning as well as parallelization of the propagation steps that are associated to each individual action composing a plan.

The activities of KLA have been supported by several agencies, including the National Science Foundation, the National Institute of Health, and the Department of Education.

Humanitarian Tech 2014 Conference

13-15 May 2014
Boston, MA

Call for Papers open through 31 Jan 2014

http://www.humanitariantechnology.org/

Joint Interagency Field Experimentation (JIFX)
14-2 Event Call for Papers

10-13 February 2014 at Camp Roberts, CA

Whitepaper submissions are due no later than **8 January 2014**

Please visit the JIFX website (http://www.nps.edu/Academics/Schools/GSOIS/Departments/IS/Research/FX/JIFX/JIFX.html) to review the Request for Information (RFI) and apply for attendance.

E-mail Tristan Allen (jifx@nps.edu) for additional details

CRUSER Monthly Meetings

Mon 27 Jan, 1200-1250 (PST)
Mon 24 Feb, 1200-1250 (PST)
Mon 17 Mar, 1200-1250 (PST)
Root 272, VTC, or dial-in 831-656-6685
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Short articles of 500 words for CRUSER News are always welcome - cruser@nps.edu

- Unmanned Systems/Robotics research
- New Program/Systems/Projects
- Other aspect of Unmanned Systems/Robotics

STUDENT CORNER

Student: Junwei Choon

Title: DEVELOPMENT AND VALIDATION OF A CONTROLLED VIRTUAL ENVIRONMENT FOR GUIDANCE, NAVIGATION AND CONTROL OF QUADROTOR UAV

Curriculum: Mechanical Engineering

Abstract:

This thesis is focused on the development of a six degrees of freedom (6DOF) simulation model of a commercial-off-the-shelf quadrotor. The dynamics of the quadrotor and its control strategy are described. The Geometric Dilution of Precision (GDOP) of the Autonomous Systems Engineering and Integration Laboratory (ASEIL) laboratory used in conducting the experiments is also analyzed. Simulation results are then verified with actual flight data.

A direct method of calculus of variations is employed in the development of an algorithm for optimal trajectory generation and collision-free flight. Using the differential-flatness characteristics of the system, the trajectory optimization is posed as a nonlinear constrained optimization problem in virtual domain, not explicitly related to the time domain. Appropriate parameterized functions employing an abstract argument, known as the virtual arc, are used to ensure initial and terminal constraints satisfaction. A speed factor maps the virtual to the time domain and controls the speed profile along any predetermined trajectory. An inner loop attitude controller was used to achieve almost global asymptotic attitude tracking for trajectory following. The trajectory generation and following algorithms were verified using the 6DOF simulation model through a simulated collision avoidance scenario.

Cont from page 1

LT. Josh Weiss developed a hydrodynamic model, which captures the motion and response of the platform to control inputs, as his Masters Thesis research (presented at IEEE Oceans 2013 [3]). The approach is based on online System Identification techniques.

Figure 8: NASA Aquanauts with the NPS REMUS 100 and THAUS in front of the Aquarius Reef Base.

Furthermore, the robot diver assistant must share the operating environment with human divers and operate in close proximity to the sea bottom (reefs, rocks, over-hangs, etc.). Three initial navigation capabilities have been identified to enable a basic diver assist capability: station keeping, navigation to a specified location in the operating space, and diver-relative navigation. LT Andrew Streenan (USN) investigated this problem in his Masters Thesis research: diver-relative navigation and avoidance was accomplished via Artificial Potential Fields and site-relative navigation with diver leading required a deliberative planning approach that leveraged the RRT* algorithm [4] and trajectory execution which accounts for diver motion. These results were presented at IEEE Oceans 2013 conference [5].

Finally, CAVR established a collaborative partnership with NASA Johnson Space Center and participated in the NASA Analog Studies SEATEST II field experiment in September 2013. The experiment spanned 2 weeks and took place at the Florida International University (FIU) Aquarius Reef Base [6] in Key Largo, FL. NPS deployed 2 REMUS 100 AUVs and THAUS to perform wide-area surveys (REMUS), share information between dissimilar vehicles (REMUS and THAUS), and provide basic diver support with THAUS. This initial collaboration was partially supported by CRUSER.

For additional details and videos please refer to:

- http://www.nps.edu/About/News/NPS-NASA-Collaborate-on-Human-Robot-Interaction-in-Extreme-Environments.html
- http://www.nps.edu/About/Publications/diverassist.html

[1] http://www.nasa.gov/exploration/analogs/

[2] http://www.seabotix.com/products/vlbv300.htm

[3] Weiss, J.D. and Du Toit, N.E., "Real-Time Dynamic Model Learning and Adaptation for Underwater Vehicles", MTS/IEEE Oceans Conference, Sept. 23-26, San Diego, CA, 2013

[4] S. Karaman and E. Frazzoli, "Sampling-based algorithms for optimal motion planning," The International Journal of Robotics Research, vol. 30, pp. 846-894, 2011

[5] Streenan, A. and Du Toit, N.E., "Diver Relative UUV Navigation for Joint Human-Robot Operations", MTS/IEEE Oceans Conference, Sept. 23-26, San Diego, CA, 2013

[6] http://aquarius.fiu.edu/