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CRUSER NEWS

Consortium for Robotics and Unmanned Systems Education and Research

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

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Extended autonomy capability for the ScanEagle UAV

by Dr Noel DuToit, NPS faculty, nedutoit@nps.edu

Figure 1: Boeing/Insitu ScanEagle UAV

The Boeing/Insitu ScanEagle UAV platform (Figure 1) is extensively used in theater, having logged more than 500,000 combat flight hours. NPS CAVR maintains and operates 7 of these vehicles, which are often employed during US-SOCOM-NPS TNT experimentation. However, the utility of this platform for autonomy research is limited due to semi-autonomous operation: a dedicated pilot commands the vehicle remotely, with the option of a few basic autonomous behaviors (such as loitering). For this platform to be utilized in advanced applications (e.g., autonomous multi-vehicle, multi-tier wide-area surveillance support for tactical forces engaged in maritime Visit, Board, Search, and Seizure), the platform must be able to adapt its behavior as the mission evolves. This adaptation is accomplished through onboard sensing and decision-making.

This project focused on extending the autonomy capability of the ScanEagle UAV platform by developing a secondary autopilot-architecture (aka backseat driver). This backseat driver allows the stock autopilot to be tasked from an onboard computer, leveraging the proven capabilities of the stock autopilot for execution. An onboard computer was integrated as a payload on the ScanEagle and connected to the stock autopilot. Two interfaces to the stock autopilot were implemented: waypoint execution (high-level) and angular-rate (low-level) commands. A mission management module was developed and implemented (see Figure 2a) and mission execution was demonstrated in simulation and with flight tests in Boardman, OR. Additionally, a real-time path-generation capability and a path-following controller were integrated (see Figure 2b), but could not be tested due to inherent limitations with the stock autopilot.

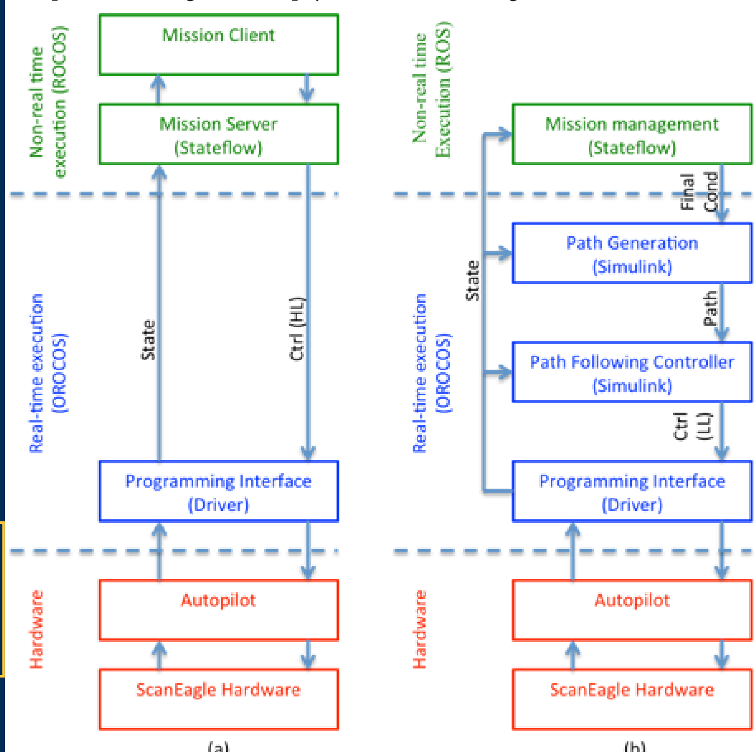

Fig 2: Secondary autopilot architecture for (a) high-level and (b) low-level control interfaces

The outcome of the project is a demonstrated, flexible autonomy architecture that allows on-board decision-making and mission adaptation as well as high-level control of the vehicle via a simple graphical interface (i.e., without the need for a forward control station) to one or multiple field operators. See http://www.nps.edu/Academics/Centers/CAVR/Research/Research.html for project details and results. This project was supported by CRUSER.

The CRUSER Community of Interest has passed the 1000 member mark. Thanks to everyone who participates, contributes, and has shared CRUSER and contributed to our growth!

Director's Corner

To build our community of interest and to share emerging research and programs CRUSER hosts an hour-long monthly meeting which all members are invited to participate by calling in or joining via VTC. The meeting's agenda includes brief administrative announcements, research and thesis opportunities submitted by CRUSER members, a fifteen minute presentation of a research topic or new program by a CRUSER member, and a quick "round robin" of information sharing. Please consider joining us for our next meeting. Ms. Lisa Trawick, CRUSER Operations Manager sends out monthly invitations with connection information.

CAPT Jeff Kline, USN (ret)
CRUSER Director

Language-Centered Intelligence (LCI): Using Language to Develop Intelligence

by Dr Dean B. Edwards, Dr Michael J. Anderson, Dr James Frenzel, Dr Terence Soule, Dr Eric Wolbrecht (UI Faculty) and Dr Noel Du Toit, Doug Horner (NPS Faculty), dedwards@uidaho.edu

In some fundamental manner, human intelligence and language are closely related. Clearly, we are the most intelligent animal on this planet and also the one having the most developed language. Try formulating a thought without using words. Certainly, visualization can be used in some thinking processes but even these processes usually make use of words in helping define or explain any pictures formed in the brain. What role, then, did language play in developing our intelligence? Is language required for our intelligence or simply an artifact or outcome of our intelligence?

In analyzing the genetic difference between humans and Chimps, who share 99% of their DNA with us, researchers have identified those parts of the human DNA code that have undergone the most rapid change since the two species diverged. Some of these DNA changes resulted in the human cerebral cortex, a larger brain, and the ability to make human speech. The human larynx allows us to speak but also can cause humans to choke. Choking is the fifth leading cause of accidental death in the United States. It is therefore not surprising that the human larynx does not exist in any other primate and indicates the importance of speech and language in our evolution. Again, this would suggest that language and intelligence evolved together.

Although understanding the role of language in developing intelligence may seem to be a very academic exercise to engineers, this understanding could inform future research directions in artificial intelligence. Is language simply a means of communicating or is it integrally associated with intelligence and required for evolving our intelligence? From an engineering point of view it may not be necessary or even desirable to evolve machine intelligence in the same manner as human intelligence. For example, chess playing algorithms take advantage of a computer's speed and ability to do extensive searches rather than to try to exactly duplicate how a human plays chess. Even so, the Turing test is based on language and knowing how our intelligence evolved could be very helpful in evolving machine or other types of intelligence.

University of Idaho researchers became interested in languages when they began investigating the use of multiple autonomous, underwater vehicles (AUVs), see Figure 1, that could communicate and cooperate with each other to perform complex missions (i.e. mine counter measure missions, signature assessment missions, etc). One of the results of this research was the development of a language which we referred to as AUVish (i.e. like English but for AUVs). The language allowed the AUV fleet to implement a number of behaviors needed for MCM and similar types of missions. These behaviors include formation flying, mine-like-object (MLO) reporting and inspection, vehicle replacement, leader replacement, reporting vehicle missing, and other behaviors.

Figure 1. UI mini AUVs being prepared for field testing

In addition, algorithms for optimizing fleet resources were also implemented. While doing this work, we realized that the language and logic associated with AUVish could be used in developing scenarios for planning purposes. We refer to this approach to developing and evaluating these scenarios as language-centered intelligence (LCI). Figure 2 shows the overall control architecture for an AUV having LCI. There are two divisions present in this diagram, the LCI module and the standard control module (denoted by the dashed boxes), and both have access to the language and associated logics. The standard module uses the language and logic module to process the messages as sent while the LCI module uses the language and logic to implement planning scenarios. This is also true for the two memory modules where the LCI memory module contains an extension of the vehicle's memory that includes hypothetical information. The planning scenarios associated with the LCI memory and language modules are kept separate from the Standard Module. The Standard Module can operate without the LCI and normally uses the LCI information only to modify or change its normal response to changes in its surroundings.

The Message Anticipation Module (MAM), shown as one of the LCI modules in Figure 2, is used to correct corrupted messages received by an AUV. Humans are remarkably adept at correcting messages and use the internal logics that determine message structure (i.e., the syntactic language logic), message content (i.e., the semantic language logic), and implications that can be drawn from messages taken together with facts about human behavior and the operating environment. In fact, some of the first "thinking" that humans may have done with language was probably thinking about what was said, both the sounds and context.

Because each AUV knows the language and logics of all the other AUVs as well as the previous status of the communicating AUV, all the listening AUVs can anticipate the message or possible messages that the communicating AUV will send.

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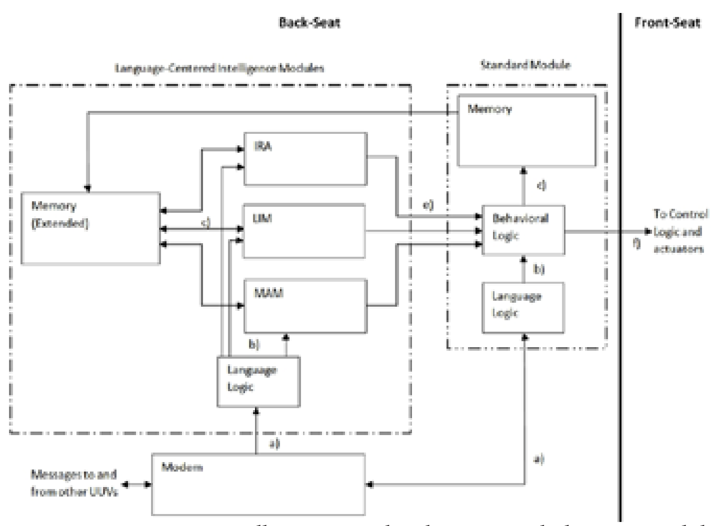

Figure 2. Overall AUV control architecture including LCI module

Memorial University – A Centre for Excellence in Applied Autonomous Systems Research

by Stephen Reddin, Project Manager for Intelligent Sensor Platforms for Remotely Piloted Vehicles, sreddin@mun.ca

Strategically located in the Atlantic Ocean on transatlantic flight paths, ocean and airborne technology is part of the past, present and future of Memorial University of Newfoundland.

A collective passion for ships is rooted in the history of the province. Vikings first made landfall on the shores of Newfoundland in about the year 1,000, nearly 500 years before Joohn Cabot made it the oldest European settled land in North America. In the 16th century, John Cabot returned and established the area as an important hub for the fishing industry, supplying Europe with much-needed food supplies. In 1919, Alcock and Brown left from St. John's, the provincial capital, and successfully made the first transatlantic flight to Clifden in County Galway, Ireland. Throughout the Second World War the province served as a mustering station for naval convoys leaving for Europe and an air base for aircraft patrolling the North Atlantic.

More recently, this collective passion has inspired leaders from engineering and business to work in new innovative areas of research on autonomous underwater vehicles (AUVs) and unmanned aerial vehicles (UAVs). Ongoing mechatronics research is focused on integrating the mechanical, electrical and computer systems of autonomous vehicles. Unlike much of the recent, publicized work that has demonstrated aerial vehicles performing missions in highly controlled laboratory environments - where most of the system intelligence is located on the ground requiring external control systems and pilots - the research at Memorial is about developing the intelligent sensor platforms that will enable truly autonomous missions whereby the platforms are able to interpret and make decisions about how to operate in their environment, only bringing relevant and useful information to the attention of pilots and ground stations. The commercial, industrial and military applications of the research performed here have not gone unnoticed, and are attracting investment and partnerships with some of the world's leading research institutions and corporations.

People

Two passionate individuals are leading much of the autonomous vehicles research at Memorial. Dr. Ralf Bachmayer's is in the field of autonomous underwater vehicles (AUVs) and Dr. Nicholas Krouglicof's research is in the area of mechatronics and unmanned aerial vehicles (UAVs). Collectively, these two researchers manage a team who are not just researching, but constructing new products that will achieve commercial readiness levels suitable for use in military and industrial applications.

Dr. Bachmayer has always been interested in autonomous underwater vehicles. Shortly after completing his first degree in Germany, he worked as a visiting researcher at the Woods Hole Oceanographic Institution in Massachusetts and then went on to complete his M.Sc and PhD degrees at Johns Hopkins University in Baltimore, Maryland. Dr. Bachmayer came to St. John's to work at the National Research Council, Institute for Ocean Technology. In 2007 he joined the Faculty of Engineering and Applied Science of Memorial University where he established the Autonomous Ocean Systems Laboratory (AOSL) that he currently heads. He has been awarded the Petro-Canada Young Innovator Award and currently holds a Canada Research Chair in Ocean Technology.

Dr. Krouglicof comes from a background in industry-academic partnerships where he has repeatedly used original research to develop innovative products with industrial applications. After graduating first from Concordia University in Montreal, Dr. Krouglicof went to work with CAE Electronics, a company that builds flight simulators for commercial and military training programs. His PhD thesis was developed from a CAE project to design a non-contact, six degree of freedom measurement system capable of tracking the position and orientation of a pilot's helmet in a tactical fighter simulation. Since then, he has worked to establish research centres at many leading institutions such as École de Technologie Supérieure (ETS) in Montreal and Union College in Schenectady, New York. Since 2006, Dr. Krouglicof has been working in the field of mechatronics, which is best described as the intersection of mechanical, electrical and computer systems to solve problems that could not necessarily be satisfied through any engineering discipline independently. Dr. Krouglicof has worked with several industrial partners, including Canadian Marconi of Montreal and Intempco Controls. He has also been instrumental in the setup of several startup businesses, including Mechtronix Systems Inc., a company he co-founded and served as president. The work he is presently doing is focused on tackling key technology challenges of UAVs through the development of new active vision systems.

Research Facilities

Memorial University has excellent environment and research facilities for building autonomous vehicles. With a landmass just smaller than California and a population of 500,000, there are large uninhabited areas perfect for testing low-altitude aerial vehicles. With an economy traditionally based on fishing and located in the middle of the Atlantic Ocean, St. John's has many remote boat launches and sheltered bays that are ideal for testing autonomous underwater vehicles.

To supplement the enormous number of suitable field testing sites, St. John's is home to world-class laboratories and research facilities, such as the National Research Council Institute for Ocean Technology. This facility houses a 200-metre towing tank, a 75 x 32-metre offshore engineering basin and a 90-metre ice tank – the largest in the world. These facilities have encouraged the development of a cluster of businesses and expertise in the area for ocean-based research.

The Mechatronic Development and Prototyping Facility is the heart of the UAV research community at Memorial. Constructed in 2012, it provides state-of-the-art equipment for design, manufacturing and testing of mechatronics projects. These resources have been applied extensively to construct integrated mechanical, electrical and computer systems for UAV research. Some of the equipment that can be found in this laboratory includes rapid prototyping equipment for manufacturing mechanical components and electronic enclosures, facilities for assembly and reworking printed circuit boards, high-performance electronic test and measurement equipment, non-conventional machining systems including laser machining equipment and chambers for the accelerated environmental and mechanical testing of mechatronic systems. Ground breaking projects currently being conducted in the laboratory include a low size, weight, and power (SWaP) pointing device for an intelligent camera system and mini quad rotors that can be manufactured from a single printed circuit board.

Past and Future

Just as Newfoundland played a pivotal role in the early era of transatlantic ocean and air travel, it is now, through Memorial University, establishing itself as a pioneering institution in the area of unmanned systems research for aerial and underwater vehicles.

http://www.mun.ca/research/ocp/MRP/intelligent-sensors/suripsin.php

Dr. Ralf Bachmayer and the Autonomous Ocean Systems Laboratory (AOSL)
Photo By: Chris Hammond

CRUSER Monthly Meetings

CRUSER monthly meetings are an opportunity to hear short presentations on current research and to participate in the open discussion session with other CRUSER members. The meetings are available via VTC or Elluminate to watch the presentation and audio is available via dial-in.

Contact Lisa to schedule a presentation at cruser@nps.edu

STUDENT CORNER

Student: LT Timothy Stevens, USN

Title: Nondeterministic Search Pattern Optimization for Minimization of UAV Counter-targeting

Curriculum: Operations Research

Abstract: In an attempt to mitigate the expanding counter-UAV capabilities of adversary countries developed in response to the United States' increased reliance on these platforms, we apply a nondeterministic search pattern to a finite area searcher. By implementing a Levy distribution on search leg lengths we analyze the trade-offs between efficiency and evasiveness of the searcher, comparing the expected time to target detection for a given set of Levy parameters to a probabilistic time to counter-targeting of the searcher based on estimated enemy capability. The goal of this thesis is the development of a simulation platform through which to establish a set of Levy parameters resulting in the largest probability of mission success, defined as the probability that the expected time to target detection is less than the expected time to counter-targeting by the adversary. The robust design of the simulation allows for analysis of nondeterministic search strategies for various searcher platform characteristics and distributions on search leg lengths.

Does your DoD Organization have a potential thesis topic for NPS Students? Contact us at CRUSER@nps.edu

em2 MMOWGLI

by Dr Don Brutzman, NPS Faculty, brutzman@nps.edu

To generate innovative ideas from a broad field of participants, Navy Warfare Development Command (NWDC), the Office of Naval Research (ONR) and the Naval Postgraduate School (NPS) are partnering to conduct a crowd-sourcing online war game on electromagnetic maneuver (em2, pronounce "E M squared").

The em2 MMOWGLI game is available in three one-week moves (phases), 24-hours a day:

- Move 1: "Know the EM Environment: Understanding EM Energy"
- Move 2: "Be Agile: C2 in the EM Environment"
- Move 3: "Change Our Paradigm: Tactical Employment of EM Weapons"

This group effort is already underway and generating large numbers of innovative concept ideas and action plans. Participation is limited to U.S. citizens. Players can register using their .mil address, or request permission to play. Everything is done via your Web browser.

Please register and play at https://mmowgli.nps.edu/em2

Each phase of the game will start with the partners posting 'root' cards which pose questions on the topic for that phase. Players then post 'idea cards' that other players can respond to by either building on, countering, redirecting, or calling for further expertise. Points are earned based on each idea card's influence and perceived value. Individuals contributing to particularly intriguing concepts are invited to collaborate on an "Action Plan" to move that idea forward. Published action plans are awarded further points by all players providing ratings and additional comments. Crowd-sourced innovation often exposes new concepts and possibilities that have not previously been considered.

Significant player achievements will be recognized. In addition to the unclassified em2 MMOWGLI game, a blog on NWDC's Navy Center for Innovation classified website will allow military and government players with a .mil account to continue discussions in a secure environment. Results of the game will be used to inform Navy innovation concept development and experimentation efforts.

Use of the EM environment affects perhaps every aspect of unmanned systems and military operations. This work directly builds on the concepts published by CNO Admiral Jonathan Greenert USN in the U.S. Naval Institute _Proceedings_ on "Imminent Domain," December 2012.
http://www.usni.org/magazines/proceedings/2012-12/imminent-domain

Play the game, change the game!

Upcoming CRUSER Monthly Meetings

Fri 15 Feb 2013, 1200-1250 (PST)

Root 242, VTC, or dial-in 831-656-6681

Fri 15 Mar 2013, 1200-1250 (PST)

Root 242, VTC, or dial-in 831-656-6681

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If the received message is corrupted, then the LCI MAM module on a receiving AUV can compare the corrupted message to the anticipated messages and make a decision on what the correct message was. Using computer simulations and randomly flipping bits, we have found that the MAM presently being used can improve the success rate of transmitting a message from about 90% to 99.8%. In the field we typically find the uncorrected success rate to be 80-90%. This improvement in actual practice would be very welcomed and perhaps, in some sense, the AUVs are evolving in a manner similar to humans.

Dr. Edwards, who is on sabbatical at NPS from the University of Idaho (UI), along with other UI and NPS researchers, are investigating the use of voice communications to control autonomous vehicles. NPS researchers are developing a robotic diver assistant to facilitate joint robot-human underwater operations, which in turn requires diver-robot communication in a noisy communication environment. Initially these researchers are interested in controlling the hovering underwater vehicle shown in Figure 3 to give surface operators and/or divers a reliable and unobtrusive command interface with the vehicle. Eventually, they would like to control multiple vehicles where the vehicles can also communicate with the operator/diver as well as the other vehicles in their group. The researchers are also interested in robots that can interpret the general intent of verbal commands and implement meaningful actions without detailed instructions from the operator. This ability would allow for more capable, flexible, "intelligent" systems.

Figure 2. Overall AUV control architecture including LCI module