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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

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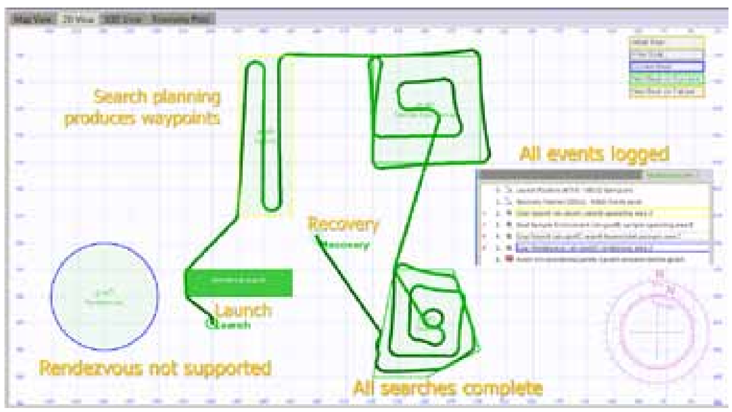
Run-Time Ethics Checking for Autonomous Unmanned Vehicles: A Practical Approach

by Dr. Don Brutzman, Dr. Duane Davis, Dr. Robert McGhee and Terry Norbraten, NPS faculty, brutzman@nps.edu

Recent years have shown that the concept of robot ethics is important for establishing norms on allowed behaviors for unmanned systems. However, approaches considered to date are either based on highly abstract artificial intelligence (AI) schemes or else uniquely "hard wired" into a given robotic architecture in an unrepeatable fashion. A more-general approach is needed for defining and deploying ethical constraints on robotic systems that are expected to operate autonomously.

Current research work at NPS has demonstrated practical approaches for ethical reasoning to govern robot behaviors consists of applying ethical constraints to existing patterns of robot planning, rather than creating some new paradigm for philosophical contemplation. This approach is intentionally patterned after similar patterns used by military forces, which often must operate in a loosely coordinated fashion while observing highly consistent rules of engagement (ROEs). Our focus is on maritime robotics supporting fleet and coalition forces.



Three key insights inform this work. First is that humans working in military units are able to deal with these challenges without ethical quandaries; unmanned systems need to compatibly follow operations orders and ROEs under loose supervision, just as any other military unit might. Second is that ethical behaviors don't define the mission plan, rather ethical constraints inform the mission plan. Ethical tasking is a modification of regular tasking, not an entirely new philosophical paradigm. Third is that the most-promising path forward lies in producing general mission orders that are understandable by (legally culpable) humans, then reliably and safely executable by robots.

Project results include defining, evaluating and visualizing tactical missions for unmanned systems using open-source NPS simulation software, the Autonomous Unmanned Vehicle (AUV) Workbench. Innovative, influential thesis opportunities are now feasible that can rehearse robot operations using simulation prior to field testing. The challenges involved in defining and executing ethical robot operations show that "everything old is new again," warfighters have greater moral, tactical and technical responsibilities than ever before. This work opens a practical door leading into that necessary future.

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MMOWGLI is an online game designed to find and collectively grow breakthrough solutions to some of our most urgent problems. In 2011, thousands of players contributed tens of thousands of ideas to turn the tide of global piracy. In 2012 another large MMOWGLI game was played to find innovative ways to increase the energy effectiveness of the U.S. Navy and Marine Corps.

The Navy's new Open Systems Architecture (OSA) strategy presents an aggressive challenge to Naval Acquisition experts: can we realign to eliminate redundant development, improve competition, and provide more timely war fighting capability. Beginning now, and through the remainder of this decade, fiscal realities will require Systems Commands and PEOs do more with less in order to provide effective and sustainable systems to the fleet. The OSA strategy is motivated by these realities - Navy and industry must succeed together.

Please join the bii MMOWGLI game 14-20 Jan and contribute your knowledge: https://portal.mmowgli.nps.edu/bii

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Report Documentation Page

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Director's Corner

As robotics and unmanned systems technologies advance and expand, so does the richness of the communities and disciplines they involve. Given how quickly the unmanned systems world is changing, it is even more important that we strive to redefine our respective professional, technical, and academic comfort zones to include new perspectives, dialogues, and collaborations. As seen in this issue, ranging from topics such as human factors, cultural impacts, and social implications, to ethical considerations, business and cost analyses, and policy, inclusion of these issues alongside other technical elements is critical (and invited) to the unmanned systems conversation.

Dr. Timothy H Chung
CRUSER Director, Research and Education

The Virtuous Robot

by Don Howard, Professor at Notre Dame, dhoward1@nd.edu

Autonomous weapons systems are already a reality – witness the Phalanx CIWS and its land-based C-RAM cousin– and the development of more sophisticated such systems, including both defensive and offensive systems, is an inevitability, even though Human Rights Watch has called for a total ban on "Killer Robots." The question regarding moral robots is not, whether, or even, when, but, how.

The dominant paradigm in designing "ethics modules" for autonomous systems combines rule-based deontological reasoning with consequentialist calculations of the net utility of various possible courses of action. Does a given action violate a fundamental moral or legal rule, such as the principles of the Law of Armed Conflict? Do the number of expected non-combatant casualties exceed a threshold deemed acceptable for the achievement of a legitimate military goal? Often dubbed the "decision-tree" approach, this is easy to program and an essential component of any fully autonomous system. Its use is defended on grounds of moral transparency and predictability. But as Plato warned us over 2,000 years ago, one cannot write a rule to cover every contingency. Moreover, utilitarian calculations confer spurious objectivity on complicated moral decision making. Who, for example, sets the threshold, and how?

An alternative approach is inspired by the virtue ethics tradition, which focuses less on the morality of individual actions and more on the moral character embodied in settled habits of action. Does this agent tend, in the main, to act in the manner appropriate for the given circumstances? As Aristotle taught, moral character is developed first by the community's intentional shaping of the young person's behavior and then by the agent's modeling his or her behavior on the pattern of morally exemplary individuals. Advantages of this approach include flexibility, adaptability, and swiftness of action flowing from ready dispositions to act. How to inculcate "virtue" in a machine is the problem. The answer lies in the employment of sophisticated, new machine learning techniques, foremost among them genetic algorithms. Copying the Darwinian evolutionary scheme of reproduction with variation and selection, a primitive code mutates and evolves as machine behavior improves in accord with selection criteria. Genetic algorithms have proven their superiority over more than thirty years in computationally intractable tasks such as predicting market behavior and facial recognition. Evolved codes defy easy reduction to rule sets, but worries about transparency should be allayed by superior performance in complicated decision settings, and the genetic mode of learning maps easily the moral modeling central to the virtue ethics tradition.

Don Howard, is Professor of Philosophy and Director of the Reilly Center for Science, Technology, and Values (reilly.nd.edu) at the University of Notre Dame, a major project of which is ETNSI – Emerging Technologies of National Security and Intelligence.

Librarian's Corner:

California Polytechnic State University, Case Western Reserve University – "Enhanced Warfighters: Risk, Ethics, and Policy"

Abstract: The United States military is making substantial investments to develop technologies that would enhance the ability of warfighters to complete their missions safely and effectively. Driven by neuroscience, biotechnology, nanotechnology, robotics, and other emerging technologies, this research includes combating sleep deprivation, improving cognitive performance, increasing strength, reducing muscle fatigue, and other enhancements to the human body and mind. As with other emerging military technologies, such as robotics and cyber-capabilities, human enhancement technologies challenge existing laws and policy, as well as underlying ethical values. But while the implications of human enhancement generally have been widely discussed, little analysis currently exists for the military context--specifically operational, ethical, and legal implications of enhancing warfighters, such as: How safe should these human enhancements and new medical treatments be prior to their deployment (considering recent controversies such as mandatory anthrax vaccinations)? Must enhancements be reversible or temporary (considering that most warfighters will return to society as civilians)? Could enhancements count as 'biological weapons' under the Biological and Toxin Weapons Convention (considering that the term is not clearly defined)? This report begins an investigation into these and other issues in order to identify problems that policymakers and society may need to confront.

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Unmanned Air Systems for Maritime Surveillance: Developments and Operations

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Ricardo Bencatel, Ricardo Martins, José Pinto, Laboratório de Sistemas e Tecnologias Subaquáticas, Engineering Faculty, Porto University

Portugal has one of the largest Exclusive Economic Zones of the European Union countries. In addition, Portugal has jurisdiction over Marine Protected Areas located beyond the 200 Nm limit, and possible extensions of the Continental Shelf will reach 400 Nm in some regions. This poses significant challenges to maritime surveillance, especially in troubled economic times.

The PITVANT UAS project is developing systems and technologies to address some of these challenges, namely those pertaining to air maritime surveillance. The PITVANT project, funded by the Portuguese Ministry of Defense, is a 7 year collaborative program undertaken by the Portuguese Air Force Academy and Porto University (Faculty of Engineering, Faculty of Sciences and INEGI). The project started in 2008, and has four main thrusts: 1) development of three types of small and medium sized UAS for dual-use operations; 2) development of concepts of operation; 3) testing and evaluation of UAS in a wide range of civil and military mission scenarios; and, 4) training of military personnel. The three types of PITVANT UASs are briefly described next:

- Mini-UAS – fixed wing, battery powered, hand-launched, with a wingspan of 1.8m, maximum takeoff weight (MTOW) of 3Kg, and 40 minutes endurance.
- Alfa - fixed wing, with a wingspan of 2.4m (3.6 m in the E version), MTOW of 18 Kg (28 Kg in the E version), combustion or electric engines, and 4 hours endurance (14 hours in the E version).
- Antex - fixed wing, with a wingspan of 6.5m, MTOW of 150 Kg, combustion engines, and 8 hours endurance.

Alfa Extended UAS

Antex UAS

The PITVANT UASs have modular onboard computer systems and payloads. Payloads include video cameras (visible, infrared and multispectral), AIS transponders, and environmental sensors. The ground stations include, in addition to dedicated computer systems, directional antennas for communications.

The PITVANT control architecture is targeted at networked operations and inter-operability (e.g., it is partially compliant with the NATO STANAG 4586). Vehicles are abstracted as providers of maneuvers and services, which are made available through standardized interfaces. There are maneuvers for single vehicle operations and for multi-vehicle control.

The control architecture has an off-board component and an on-board component. These are implemented with the help of the Neptus-IMC-Dune software tool chain. Neptus implements the off-board distributed command, control, communications and intelligence component. IMC is a communications protocol defining a common control message set for all types of PITVANT nodes (vehicles, consoles and standalone sensors). Dune is the system for vehicle on-board software. It provides an operating-system and architecture independent C++ programming environment for writing efficient real-time reactive tasks in modular fashion. The tool chain has support for Disruptive Tolerant Networking (DTN) protocols. The tool chain is also used for autonomous underwater and surface vehicles (ASV). This allows networked operations with non-PITVANT vehicle systems such as the Seacon Autonomous Underwater Vehicles (AUV) developed by Porto University for the Portuguese Navy. Currently we are working with MBARI on the integration of the deliberative onboard planning system TREX with Dune. This will increase the level of autonomy of the platforms.

The PITVANT air vehicles have accumulated over 800 autonomous flights. These include night operations and flights over the ocean, as well as participations in the REP exercises organized by the Portuguese Navy in cooperation with Porto University.

The REP-12 exercise took place off the coast of Sesimbra, Portugal, but continued further north from the Santa Cruz airfield. It involved participants from MBARI (USA), Centre for Maritime Research and Experimentation (NATO), Evologics (DE), Technion (IL), Norwegian University of Science and Technology (NOR) and University of Rome (IT). Several large and small propeller-driven ASVs, AUVs with different sensors and acoustic modems, as well as the wave-propelled Wave-Glider ASV (from Liquid Robotics, Inc.) were deployed from Bacamarte, a ship from the Portuguese Navy. Several PITVANT UAS were used in these experiments, some being deployed and recovered from civilian airports under monitoring of the Portuguese Air Force, and others launched and recovered aboard Bacamarte. An important REP-12 undertaking was UAS surveillance of maritime traffic in shipping lanes to monitor illegal oily water discharge and trajectory, ships in distress or adrift.

In 2013, we will flight test a navigation system integrating a compact, light, low cost inertial measurement unit with a GNSS Receiver in the GATE (Galileo Test and Development Environment) test area in Berchtesgaden, Germany. We will also demonstrate maritime surveillance capabilities in long duration flights (over 12 hours) departing from the island of Porto Santo to the Selvagens islands (over 600 Km roundtrip). This will be done with the AlfaE type UAS equipped with satellite communications. Preliminary test flights will be used for science missions in the Madeira Islands. This is because the PITVANT project is also about pragmatic cooperation with Portuguese and foreign institutions. For example, researchers from PITVANT have participated in several editions of the TNT exercise organized by the NPS.

Upcoming CRUSER Monthly Meetings

Tues 15 Jan 2013, 1200-1250 (PST)
Root 242, VTC, or dial-in 831-656-6681
Fri 15 Feb 2013, 1200-1250 (PST)
Root 272, VTC, or dial-in 831-656-6685

Short articles of 300-500 words for CRUSER News are always welcome - cruser@nps.edu

STUDENT CORNER

Student: LT Colin G. Larkins, USN

Title: The EP-3E vs. the BAMS UAS An Operating and Support Cost Comparison

Curriculum: Information Warfare Systems Engineering

Abstract: The battlefield is constantly changing and the need for swift, persistent intelligence, surveillance and reconnaissance (ISR), has increased the focus on the use of unmanned aerial vehicles (UAVs) to help meet collection requirements. Certain UAVs can have longer dwell and on-station times than manned vehicles, with some UAVs capable of dwell times in excess of 20 hours. UAVs have an additional benefit of eliminating some of the risks associated with manned aircraft conducting ISR missions. Consequently, UAVs have been closely reviewed as a replacement craft for several manned ISR aircraft and have taken increasing roles in the world of ISR. Given an uneven record of success in the implementation of UAS, and Congressional concerns regarding the relative cost of UAV programs, the purpose of this thesis is to reexamine, compare and analyze the Operating and Support (O and S) costs for both the EP-3E ISR aircraft with the Broad Area Maritime Surveillance (BAMS) Unmanned Aerial System (UAS) that the Chief of Naval Operations (CNO) has declared to be the primary system to replace the EP-3E capability. This comparison includes all costs from initial system deployment through the end of the platforms service life. This thesis uses the revised O and S cost methodology in accordance with Department of Defense (DoD) Instruction 5000.2, Operation of the Defense Acquisition System. In addition, a typical O and S comparison, this thesis modifies the existing BAMS O and S costs to account for the additional costs of bandwidth, ground station support, collection sites, and risks as they apply to the BAMS UAS. These factors were not adequately considered in the original O and S analysis. Once the analysis and comparison is completed, a recommendation is made as to whether or not the decision to replace the EP-3E ISR system with the BAMS UAS should be revisited.

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

Roadmap for Reduction of Total Ownership Cost (TOC)

by Dr. Dan Nussbaum, Professor in the Operations Research Dept at NPS, danussba@nps.edu

According to the methodology section of our proposal, we planned to research 4D/RCS and Technomics to accomplish our objectives. We analyzed the implications of using 4D/RCS as a common architecture for all UAVs, and drafted a white paper on this topic. We have also researched a paradigm shift in UAV cost estimation, which will take the form of a student thesis by LT K. Beth Jasper. Instead of focusing on Technomics, however, we decided to look at whether the use of an Open Architecture model for unmanned systems resulted in cost savings. LCDR Paula Firenze completed a thesis on this subject in June 2012.

1. 4D/Real-time Control System (4D/RCS)
The trend of increasing drone missions, with respect to missions for manned aircraft, shows that drone missions may be the way of the future. As such, the O&S costs of UAVs must be optimized. The 4D/RCS architecture is a hierarchical control structure that addresses the problems faced by an intelligent vehicle system, such as a UAV, to accomplish mission goals. In 4D/RCS, the lowest cost plan is always implemented. There are a number of cost functions at each level within the architecture to determine the planned action at that particular level.

For example, the 4D/RCS architecture should use the fewest number of UAVs to accomplish a particular mission. This saves on fuel costs because fewer UAVs would be travelling to the target location. By optimizing UAVs with regards to the missions performed, there will also be an increase in life cycle for the UAVs in the squadron and fewer wasted man-hours because the UAVs will need fewer repairs within a given time period.

2. A paradigm shift in UAV cost estimation
The purpose in this part of the project is to provide a TOC that reflects the end-to-end costs associated with ISR platforms. We do this by developing an amended, and expanded, Work Breakdown Structure (WBS) within the standard cost estimating methodology. Additional WBS elements include:

- C2 Function
- Data uplink
- Bandwidth
- Intelligence manning
- Data storage
- Software licensing
- Exploitation hardware
- Processing hardware
- Ground support elements

Research Questions that we are addressing through this approach are:

- What are the total costs associated with manned and unmanned aerial vehicles from exploitation to the dissemination of intelligence?
- What are the costs associated with measuring bandwidth as UAV's become operational?
- What are the Measures of Effectiveness (MOEs) to construct the balance between manned and unmanned aircraft from an Intelligence, Surveillance, and Reconnaissance perspective?
- How should the Navy balance UAV cost with capability?
- How should the Navy best characterize UAV costs to ensure the total cost is fully recognized?
- Is there value in analyzing other manned aircraft within the DOD that could provide a manned capability equivalent to unmanned at a cheaper cost?

Results will be available upon completion of LT Jasper's thesis in March 2013.

3. Open Architecture (OA)
While there are savings that could potentially be achieved by using OA, especially in conjunction with a Common Architecture, the Navy must be careful when and how it chooses to use the OA. There are risks that could potentially cost more than any savings OA might be able to achieve. There are three potential areas in which using OA might result in cost savings: reuse, open source, and interoperability.

In order to quantify the effects of reuse, SLOC and equivalent SLOC (ESLOC) data from the BAMS program were analyzed. The data showed a savings of $1.4 Billion, but all of this savings was attributed to opportunistic reuse as opposed to OA.

The open source part of the thesis drew data again from the BAMS program. By using Linux OS instead of VxWorks OS, the program was able to save $2.9 Million over the assumed 20-year life cycle of the program (assuming 25 licenses). The problem with open source code is security. More money may need to be spent on developing tighter and more layers of security, so some of the savings achieved by reusing the code may be offset by the need to write multiple types of security for the same code.

The interoperability section was focused on ground control station and the Navy's attempt at developing a Common Control System in which it owns all data rights. It is unclear whether this would in fact save money, as the BCA did not include any data rights costs, and the projected number of UAVs that would participate was reduced from six to three. The Army has developed a similar system, however it is proprietary.