ISSUE 20 OCT 2012

CRUSER · NEWS

Consortium for Robotics and Unmanned Systems Education and Research

FROM TECHNICAL TO ETHICAL...FROM CONCEPT GENERATION TO EXPERIMENTATION

CONTENTS

JOIN the CRUSER Community of Interest
http:\\CRUSER.nps.edu

Passive UxV Navigation using Visual Sensors

by Prof Roberto Cristi, rcristi@nps.edu and Prof Oleg Yakimenko, oayakime@nps.edu, NPS Faculty members

The overall goal of this research is to design a novel capability enabling unmanned vehicles to navigate with respect to a stationary or moving target with unknown position using passive inertial sensors (IMU and GPS) and mono vision (EO or IR). That includes estimating a relative position of an aerial platform intended to land autonomously onto a moving platform with no help provided by/from this platform. The research includes both theoretical study and practical implementation where the developed algorithms are to be implemented on an aerial payload delivery platform, ultra-light weight unpowered guided parafoil system, deployed from an unmanned aerial vehicle to land onto a ship's deck.

Such a system, Blizzard, consisting of a high-performance / long-endurance Arcturus T-20 UAV and Snowflake payload delivery unit, has been developed and demonstrated on multiple occasions already featuring delivering small payloads within 10 meters from a stationary target. The guidance algorithms to guide parafoil to a moving target were also developed and successfully tested. In these tests the moving target broadcasted its position to the descending platform, so that the latter could constantly recomputed the location of an intended impact point. However, a fully autonomous landing assumes no help from the target and there is where algorithms for passive navigation using visual sensor data are urgently needed. The algorithm development within this research effort is based on both simulated and actual video data collected during the aforementioned drops onto a moving platform.

While integrating vision with IMU/GPS data in order to estimate the position and velocity of a moving target several assumptions have to be made. The main assumption on the target is that it moves in a horizontal plane, which of course is the case for a moving ship or a ground platform, and it moves at an almost constant velocity (speed and direction). The latter assumption is crucial since successful landing of an aerial vehicle relies on a prediction of the target's position based on passive observations (you cannot safely land onto a maneuvering ship anyway). Nevertheless, robustness of developed algorithms allows a mild violation of this assumption.

The challenge of the problem of integrating vision with IMU/GPS data, especially for an unpowered parafoil system is that the trajectory of the payload, propelled by the winds only, loiters over the target to best take advantage of the wind profile during landing maneuvers. As a consequence the camera, which is fixed with the payload and has a limited field of view, sees the target only at certain time intervals while facing the target. This causes extensive "out-of-frame" events which, in standard implementations, cause the estimates of the target position and velocity to diverge and become unreliable. An illustration of out-of-frame event is presented in Fig.1, which shows a computer simulation where a target (ship's deck) is about to disappear from the field of view. A similar situation is also shown in Fig.2, occurred during the real flight test.

Continued on page 4

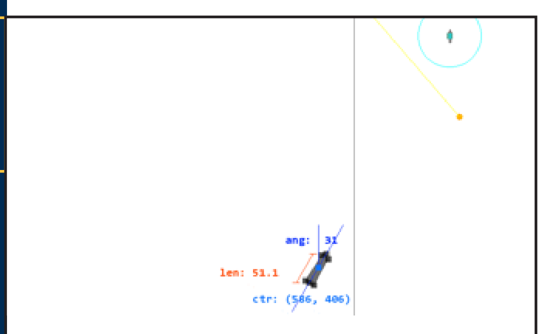

Figure 1. Computer simulation of autonomous ship landing

Figure 2. Figure 1 situation reproduced during a real test.

CRUSER is now on Facebook
"Like" us to find out about upcoming events, hear about current research and publications, pictures & videos, and to interact with other CRUSER members
https://www.facebook.com/pages/CRUSER/504463399565603

Director's Corner

For an ever-changing area of unmanned systems and capabilities, we must strive to keep up with its rapid pace of development with an equally upbeat effort in concept generation and development. We begin the new academic year and a new CRUSER Innovation Thread, starting with the Warfare Innovation Workshop (see p. 3) where innovation in concepts can mature over the next 12-18 months into reality. As we launch this new Thread alongside our concurrent one initiated last fall, CRUSER seeks to combine great concepts with operational value and relevant perspectives, and demonstrate that, indeed, CRUSER and its fellow community members can lead the way ahead in robotics and unmanned systems.

Dr Timothy H Chung
CRUSER Director, Education and Research

Legal Implications of Autonomous Weapons Systems

by Jeffrey S. Thurnher, Major, USA, Faculty, International Law Department, U.S. Naval War College, jeffrey.thurnher@usnwc.edu

As technology rapidly advances, unmanned systems are becoming more capable of making decisions without immediate, direct human involvement. There may be a time in the not too distant future when unmanned systems are able to fire upon an enemy without requiring a human in the loop. A July 2012 DOD Defense Science Board report found that autonomous technology is being "underutilized." The implication is that DOD intends to increasingly build autonomous features into its unmanned platforms. The potential use of autonomous weapons systems (AWS) on the battlefield raises significant legal issues.

While all weapons systems are required to comply with the Law of Armed Conflict and its fundamental principles, AWS would likely generate some unique concerns. For example, AWS must be capable of distinguishing between civilians and combatants. The complex battlefields of the past decade have demonstrated the practical difficulties of this task. Even the most advanced facial and other recognition software that these AWS would likely employ may find making these distinctions extremely challenging. Additionally, AWS would be obligated to take feasible precautions to minimize civilian casualties prior to attacking. There is no clear consensus on how AWS might practically satisfy that requirement. Furthermore, AWS would need to comply with the principle of proportionality, which requires that the expected collateral damage of an attack not be excessive in relation to the anticipated military gain. Such calculus has traditionally been a human judgment call and has been evaluated on the basis of reasonableness. It remains to be seen whether proportionality decisions made by AWS will be deemed to comply with the relevant legal regimes. These and other potential concerns will need to be resolved prior to the deployment of any AWS.

Political and DOD leaders are only now starting to come to grips with the gravity of these underlying legal questions. Legal scholars have also begun to take serious note and have expressed the need to actively debate these emerging topics. As part of that dialogue, the Naval War College's International Law Department intends to examine these complex problems through a legal research workshop on February 7-8, 2013. Twenty-five handpicked international law and technical experts have been selected to convene in Newport, Rhode Island, to discuss whether and how autonomous systems might comport with the Law of Armed Conflict. The goal of the workshop is to explore the legal matters in depth, elicit different perspectives on the issues, and generate new ideas about how best to deal with this developing technology.

For more information about this and other cutting edge legal research projects from the U.S. Naval War College's International Law Department, please go to http://www.usnwc.edu/ild or contact Major Jeff Thurnher at jeffrey.thurnher@usnwc.edu or (401) 841-6589.

Short articles of 300-400 words for CRUSER News are always welcome. Contact us at cruser@nps.edu for additional information.

Upcoming CRUSER Monthly Meetings

Mon 29 Oct 2012, 1200-1250 (PDT)
Root 242 or dial-in 831-656-6681
Mon 19 Nov 2012, 1200-1250 (PST)
Root 242 or dial-in 831-656-6681

Qualitative Metrics for Autonomy

by Tom Keeley, President of Compsim LLC, tmkeeley@compsim.com, 262-797-0418, http://www.compsim.com

In July, 2012, the Department of Defense, Defense Science Board issued a task force report titled “The Role of Autonomy in DoD Systems”. This document recognized the significant impact that autonomy will play in future DoD systems. It references past work and recommends future research. It highlights a number of issues that it feels still need to be addressed. And it highlights what it feels is one of the largest obstacles to progress, and that is the lack of trust in autonomous systems. Compsim made two observations while reviewing the document: 1) the authors were not familiar with Compsim’s Knowledge Enhanced Electronic Logic (KEEL) Technology, and 2) there were no metrics or guidelines listed that potentially could be used to measure or compare alternative technologies. This drove Compsim to create a list of qualitative metrics (derived from the review of the task force document) that might be used to compare alternative approaches. While these metrics do not provide quantitative measurements, they suggest topics that system builders might want to consider when they choose an approach to addressing autonomous behavior.

The list with an explanation of the driving force behind each item is available at:
http://www.compsim.com/PublicPapers/Autonomous%20Technology%20Metrics.pdf

Qualitative Metrics for Autonomy

1. Deterministic / Auditable Behavior
2. Support for Adaptive Behavior
3. Support for Autonomous Learning
4. Support for Non-linear Control
5. Support for a Dynamic Environment
6. Handles Temporal Data
7. Supports Human-in-the-Loop Decisions
8. Support for “Qualified” Data
9. Handles “Surprise” Situations
10. Deterministic Performance
11. Brittleness
12. Extensibility
13. Effort to Implement and Extend
14. Ease of Use: API
15. Learning Curve
16. Ease of Use: Development Tools
17. Ease of Use: Problem Exploration
18. Testability
19. Certifiable Code
20. Certifiable Application
21. Compatibility with COTS or GOTS Solutions
22. Platform Independence
23. Architecture Independence
24. Ability of DoD to Acquire Full Rights to the Technology
25. Dependencies
26. Weaknesses of Technical Approach

Victorian physicist, Lord Kelvin (1824-1907), is credited for the remark, “If you cannot measure it, you cannot improve it.”

When a designer is challenged with new tasks requiring autonomous or semi-autonomous behavior, the designers will go through an evaluation phase to choose the most appropriate approach to the solution. The designer will “balance” the pros and cons of competing technologies and match the most appropriate approach to the task.

With this in mind, Compsim used the above list to identify the strengths and weaknesses of KEEL Technology. This review can be found at:
http://www.compsim.com/PublicPapers/KEEL%20Technology%20Addresses%20Autonomous%20Technology%20Metrics.pdf

NWDC/CRUSER Warfare Innovation Workshop

by Lyla Englehorn, CRUSER Program Manager, laengleh@nps.edu

To directly support the NWDC Line of Operations CRUSER held a three-day and a half-day Warfare Innovation Workshop (WIW) focused on Advancing the Design of Undersea Warfare (DUSW). This WIW took place during Summer Quarter 2012 Enrichment Week from Monday, 17 September through Thursday morning, 20 September. Nearly fifty participants representing over twenty different organizations included NPS students from across campus, newly selected Strategic Studies Group (SSG) Director’s Fellows, and nominated participants from the greater CRUSER Community of Interest including NUWC, JHU/APL, Electric Boat, COMPACFLT and Battelle among others. After a series of plenary sessions including an Innovation Seminar, teams generated unmanned systems concepts in response to a near-future undersea warfare scenario.

An after action report detailing the concepts generated will be released by mid-November. Planning is also underway for a follow-on workshop scheduled for 25-28 March 2013 to take a closer look at unmanned vehicles operating solely in the undersea domain. Please contact CRUSER Program Manager Lyla Englehorn at laengleh@nps.edu to receive a copy of September 2012 workshop report or to inquire about the March 2013 workshop.

STUDENT CORNER

Student: Capt Martin Conrad, USAF

Title: DOES CHINA NEED A "STRING OF PEARLS"?

Curriculum: National Security Affairs

Abstract: Is China trying to build a "String of Pearls" in the Indian Ocean? My hypothesis is that China is not looking to build large overseas military bases in the Indian Ocean. With the revolution in military affairs and improvements in C4ISR over the last twenty years, international military bases are no longer as critical to intelligence collection and force projection as they were during the 20th century. This reduces the necessity of overseas bases to primarily serve as logistics hubs—which can be contracted out to host countries and reduce/eliminate the need to establish large overseas military bases.

This thesis attempts to prove this hypothesis by examining improvements in military capabilities that include satellites, open source intelligence, cyberspace, and unmanned vehicles. With these improvements established, this thesis examines three comparative case studies involving states that have decided to reduce their international maritime presence over the last twenty years. Finally, Chinese perceptions and behaviors are examined to determine whether China is operating according to a post-Mahan international force projection theory.

Passive UxV Navigation using Visual Sensors (cont from p1)

In the proposed approach, using standard concepts from 3D vision we reformulated the problem as a linear estimation with two distinct dynamic models, one for in-frame events (when the target is in the camera's field of view) and one for out of frame events (when the target is not in the camera's field of view). While the in frame model is fairly standard, the out-of-frame model is based on epipolar geometry by which the last observation (before losing the target) and the first observation (right after we acquire it again) can be viewed as a pair of stereo observations of the same target with unknown displacement. Camera observations together with its position and orientation can then be related to the unknown target out of frame displacement to yield the necessary observation for the dynamic model. Standard recursive optimal filtering (like Kalman filtering) can then be used to recursively track the target.

The particular feature of the developed approach is that the nonlinearities are "memoryless". In this way, the dynamic model is linear, thus guaranteeing the convergence of the estimator. However the drawback is that the nonlinear processing of the observations causes the measurement errors to be nongaussian, biased and also sensitive to the geometry of the system. More recent techniques based on the Unscented Kalman Filter were also investigated to provide the more reliable estimates in the presence of sensor errors.

The project involved extensive theoretical and trade-off studies based on both simulated and experimental data and included participation of several master students and one PhD student.

Actual implementation and integration with onboard guidance algorithm is expected to involve students and instructors of the U.S. Naval Academy who built their version of Snowflake and have seamanship training craft of the "YP 676" class equipped with and aft deck for autonomous landing trials (Fig.3).

Figure 3. Landing deck on the "YP 676" class craft

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

Librarian's Corner - GAO Report to Congressional Requestors: UNMANNED AIRCRAFT SYSTEMS

"Measuring Progress and Addressing Potential Privacy Concerns Would Facilitate Integration into the National Airspace System"

"Progress has been made, but additional work is needed to overcome many of the obstacles to the safe integration of unmanned aircraft systems (UAS) that GAO identified in 2008. GAO reported in 2008 that UAS could not meet the aviation safety requirements developed for manned aircraft and that this posed several obstacles to safe and routine operation in the national airspace system. These obstacles still exist and include the inability for UAS to sense and avoid other aircraft and airborne objects in a manner similar to manned aircraft; vulnerabilities in the command and control of UAS operations; the lack of technological and operational standards needed to guide safe and consistent performance of UAS; and final regulations to accelerate the safe integration of UAS into the national airspace system. The Joint Planning and Development Office of the FAA has provided UAS stakeholders with a framework to collaborate and coordinate their UAS integration efforts."

This and other articles are available on the Unmanned Systems Guide at https:// http://libguides.nps.edu/unmanned