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DHS S&T First Responders Group and NATO Counter UAS Proposal Interest Response

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Title

Mobile Adaptive/Reactive Counter UAS System (MARCUS)

Proposer

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Problem Statement

The capability, speed, size, and widespread availability of small unmanned aerial systems (sUAS) makes them a serious security concern. The enabling technologies for sUAS are rapidly evolving and so too are the threats they pose to national security. Potential threat vehicles have a small cross-section, and are difficult to reliably detect using purely ground-based systems (e.g. radar or electro-optical) and challenging to target using conventional anti-aircraft defenses. Ground-based sensors are static and suffer from interference with the earth, vegetation and other man-made structures which obscure objects at low altitudes. Because of these challenges, sUAS pose a unique and rapidly evolving threat to national security.

Proposed Solution

Adding sensors to mobile UAS platforms improves the detection range by bringing the onboard sensors closer to the target while decreasing the signal-to-noise ratio. The MARCUS system will include three major elements: (i) detection and identification of a potential threat UAS, (ii) tracking and assessment, and (iii) neutralization of the threat UAS, ideally by capturing it. These elements will enable a mobile, adaptive, responsive counter UAS (cUAS) system to respond to this growing threat.

Detection

Various low power and low weight sensors are currently available that can be placed on a sUAS to aid in the detection of a threat UAS. Due to the small, light-weight nature of many imagers today, long or medium wave infrared, and visible light imagers can be mounted on sUAS for the purposes of detection and tracking of other sUAS. We will draw from Sandia research that investigated temporal frequency analysis methods to allow these systems to detect, discriminate, and track farther targets with as few as 4 pixels on target. We will also draw from other existing research aimed at improving ground based detection through the use of polarized radar techniques.

Tracking

Since a sUAS is a mobile platform, it has the ability to follow a threat UAS using data generated from both ground-based and aerial-based sensors. This vast amount of data must be integrated to increase the resolution, fidelity, update rate and characterize the type of the threat UAS. To

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improve sUAS tracking capability, MARCUS will fuse different modality sensors to improve environmental robustness.

Neutralization

Just as a sUAS can incorporate a range of sensors, a sUAS can also approach a threat UAS with a combination of various neutralization techniques. With robust neutralization capabilities, a sUAS can improve the range of lethality and execute precision disablement to eliminate collateral damage and provide better means for attribution. In an extreme case, the sUAS itself can be used to intercept (e.g. collide with) the threat UAS.

Drawing from Existing Research

Reactive autonomy

The proposed work will build on foundational researched performed in collaboration between Sandia National Laboratories and the University of New Mexico. We will incorporate algorithms previously developed for the coordinated intercept of a threat UAS with stochastic dynamics via multiple pursuing UASs, using forward stochastic reachability and receding horizon control techniques. This foundational research formulated a stochastic model for threats to emulate their potentially adversarial behavior, which is compatible with the existing scalable results in forward stochastic reachability literature. The optimal state for the intercept for each individual pursuer is obtained via a log-concave optimization problem, and the open-loop control paths are obtained via a convex optimization problem. With stochasticity modeled as a Gaussian process, we have approximated the optimization problem as a quadratic program, to enable real-time path planning. We also incorporate real-time sensing into the path planning by using a receding horizon controller, to improve the intercept probabilities.

Through a collaboration with University of New Mexico, Sandia National Laboratories developed hardware and algorithms for interception and neutralization of sUAS. While many approaches have been proposed to predict future positions of a moving UAS threat, these methods provide conservative solutions and do not scale easily with the dimensionality of the state-space. We used a stochastic approach based on forward stochastic reachable sets, in which a suite of UAS pursue a stochastically moving UAS threat. Our approach 1) provides exact probabilistic guarantees, 2) does not create an unnecessarily large set of possible threat positions, and 3) can be calculated in near real-time. Using motion-tracked quadrotors running the Robot Operating System (ROS) and trajectory intercept algorithms modeled with MATLAB, indoor experiments were performed demonstrating swarm-based air to air intercept and capture. This research will transition these techniques to real-world, outdoor environments requiring integration of the algorithms with state of the art commercial hardware to demonstrate the effectiveness of the approach.

Testing and Evaluation

The final aspect of this research will draw on Sandia National Laboratories' expertise and scientific methods in testing and evaluating technologies. In particular, Sandia has developed a systematic approach to evaluating the performance of commercial ground-based systems for countering sUAS. The MARCUS program will apply these methods and practices to evaluating the effectiveness of the integrated ground- and aerial-based system under development.

Deliverables

1) Demonstration of fusing ground- and aerial-based data
2) Demonstration of intercept and tracking in relevant environment(s)
3) Demonstration of target UAS neutralization using localized effects from friendly deployed UAS
4) Demonstrate effectiveness of these cUAS methods, quantifying improvements over current commercial cUAS systems
5) Documentation to capture results and next steps at the conclusion of the project

Impact

The rapid pace of evolution of sUAS technologies is not waning. In particular, the operator interface from pilot to aircraft has seen dramatic changes in the last 12 to 24 months with the advent of ever improving autonomous navigation and control capabilities. As a result, most commercial cUAS technology solutions being developed today may be rendered irrelevant in the very near future. Therefore, it is critical that significant advancements in cUAS technical approaches be made. The research proposed in the MARCUS program has the potential to better address not only today's sUAS threats, but also future instantiations of UAS technologies.

Potential Partners

We propose a joint partnership between Sandia National Laboratories and the University of New Mexico through the direction of the Department of Homeland Security First Responders Group and an appropriate, yet to be determined, international partner.

ROM Budget

$500,000 U.S. per year for 3 years (not including funding for international partner).

Note: For the full proposal, the project and budget will be proposed with a phased approach with key milestones set on an annual or semi-annual basis so the project can be evaluated incrementally as it progresses.