**U.S. Coast Guard Academy; Department of Engineering**

**Electrical Engineering & Cyber Systems Section**

Capstone Projects in EE/CYS 1 F21

Unmanned Aerial Vehicle: Research Paper

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1. **Introduction**

Unmanned aerial vehicle, or UAV, research has been a focus of private and commercial industries over the past several decades. These compact platforms often require less operating space, advertise lesser acquisition and operating costs, and minimize operator risks when compared to their manned counterparts. UAVs can be separated into two distinct categories based upon their control characteristics: autonomous or remote-controlled vehicles. Autonomous UAVs operate independently of a human operator and rely on their own control system, while remote-controlled platforms require the input of a skilled operator. Further, the two platforms of UAVs covered in this literature review, fixed-wing and quadcopter, have different maneuvering characteristics. Generally, fixed-wing vehicles provide greater energy efficiency but poorer maneuvering capabilities while quadcopters are highly maneuverable but provide shorter flight times. Each category of UAV can serve as a platform for advanced surveillance and detection equipment and, thus, has gained Coast Guard interest for their potential to benefit nearly all statutory missions – search and rescue, law enforcement, fisheries enforcement, drug interdiction, and migrant interdiction. In this report, the U.S. Coast Guard’s capability gaps with respect to the implementation of UAV technology are identified and compared to ongoing academic research. These challenges are analyzed with respect to the groups capstone research, and several focus areas are identified for future research.

In recent years, the desire to create collaborative swarms of UAVs, or autonomous systems of drones that are collectively more intelligent and efficient than the sum of their individual systems, has dominated research focuses and gained substantial funding [1]. In fact, many researchers believe the inevitable focus of future UAV research is “towards clustering, autonomy and intelligence.” [1] This systems of systems approach lies outside the scope of our capstone research but has produced a vast quantity of UAV-centered research. As a result, the general control and automation of quadcopters has been heavily studied. Well documented, publicly available, and open-source control software exists and utilizing this software will enable our group to focus our research towards addressing Coast Guard specific capability gaps.

**II.** **Current Coast Guard Technologies**

The Coast Guard began to incorporate drones into its daily operations in 2014; however, the technology is still in its infancy. The only UAV currently approved for Coast Guard operations is the Boeing Insitu ScanEagle. The ScanEagle is a fixed wing drone primarily designed for spotting and tracking vessels in the water. Thus far, ScanEagle has proven useful for larger Coast Guard Cutters patrolling for drug smuggling vessels. Testing of the system from 2014 to 2018 delivered “16 interdictions with $350M of contraband seized and 55 suspects apprehended” onboard National Security Cutter USCGC Stratton [2]. While the ScanEagle appears to be successful as the Coast Guard’s first UAV, it still lacks certain capabilities that prevent it from deploying fleet-wide. First, the system is not autonomous, meaning a well-trained drone pilot must be onboard and able to fly the UAV. It follows then that the ScanEagle is constrained by its human operator – the drone has no autonomous target identification capabilities. Furthermore, all ScanEagle platforms require a dedicated launching and landing mechanism [2]. Cutters with limited deck space are not capable of using the system. Finally, few units have been granted access to the ScanEagle drones. Each of these individual issues have compounded over time and, in combination with budget constraints, have limited Coast Guard UAV innovation and expansion.

One of the first problems that can be addressed with the current ScanEagle platform is the launching mechanism and the space constraints it introduces. The thought for the Coast Guard to utilize a vertical take-off and landing, or VTOL, UAV allows for widespread deployment of such a platform – even in places perhaps not previously thought possible. A sufficiently small UAV with VTOL capabilities could be deployed most anywhere including small boats, aviation assets, and, of course, cutters. Unfortunately, this solution is not as clear cut as it may seem.

**III.** **Computer Sensing Applications**

VTOL capable UAVs requires a significant framework of sensors and guidance in order to safely and consistently land [3]. This framework may consist of video-enabled cameras, LIDAR sensors, and GPS modules; it requires a greater level of accuracy than is provided by traditional navigation systems [4]. As with any system that accepts multiple inputs, development of decision matrices and input weights are critical in ensuring proper and consistent landings of VTOL enabled UAVs. The development of such a landing framework will ultimately comprise significant development time as well as entail budget consumption. Fortunately, many of the technologies needed to properly implement such a landing framework are readily available in a laboratory environment and can be tested at little to no cost.

It is also important to speak to the autonomy of a proposed UAV. While ScanEagle drones are intended as remote-controlled platforms, autonomous drones could be implemented to complete Coast Guard missions most efficiently. With respect to the considerable expense and significant man-hours required to qualify a ScanEagle operator, it may be cheaper and more effective to deploy a large number of drones equipped with automatic target identification capabilities. In fact, even in a one-on-one comparison, properly configured automatic target acquisition tools were approximately three times more effective than a trained human operator at detecting targets of interest in water [5]. As with the landing framework, some technologies relevant to this automatic sensing are fortunately readily accessible in a laboratory environment. IR technologies combined with relatively simple machine learning models can be implemented even on civilian-grade hardware to great effect.

**IV.** **Flight Control Automation**

A major challenge the Coast Guard may face in adapting autonomous drone use lies in the controllers each drone utilizes. Interest in this specific program has been prolific with many different studies being conducted onto the best way to control drones under a variety of different circumstances. One particularly relevant study was conducted by Allison Ryan and J. Karl Hedrick into UAV-assisted search and rescue. Their research focused predominately on methods of controlling a fixed-wing UAV that would fly alongside Coast Guard rotary-wing assets and perform redundant IR-based scans of the environment. It was determined, at the time of the study, that difficulties with maneuvering greatly limited the safety and effectiveness of joint rotary-wing and drone assets. Various path-planning rules were required to be developed in order to minimize overlap and maintain “safe separation between the UAV and helicopter” [6]. Suggestions in Ryan’s and Hedrick’s paper indicated that more powerful trajectory tracking controllers would be required to safely implement UAVs into search and rescue operations.

A quadrotor drone is relatively new technology and offers many advantages compared to the UAVs described in Ryan’s and Hedrick’s study. While with fixed-wing UAVs it might be necessary to devote large amounts of resources towards flight control, quadrotors can operate under far fewer limitations. With the ease of maneuverability quadrotors offer, controllers and path planning both respectively become simpler and simpler. In the study, it was determined that an off-the-shelf flight controller was not sufficient for the Coast Guard’s purposes. In the case of an arbitrary quadrotor, an off-the-shelf controller may prove more than sufficient. One limitation perhaps not yet considered lies in the power usage of each platform. Search and rescue operations may encompass several hours of continual operation, and – as such – any drone must be capable of operating for extended periods of time. As stated in “Design and performance analyses of a fixed wing battery VTOL UAV,” quadrotors have one major disadvantage to fixed-wing drones: power consumption [7]. Fixed-wing vehicles tend to be far more efficient; therefore, there must be a consideration made towards the operational limits this would place on search and rescue operations. There is a tradeoff, then, to be made between the maneuverability offered by quadrotors as well as their decreased operational timeframe.

**V.** **Conclusions**

According to Yasmin Tadjdeh, the Government Accountability Office (GAO) has declared that the Coast Guard cannot afford many future projects due to the billions of dollars paid for the creation of the Offshore Patrol Cutter (OPC) [8]. Michele Mackin, also known as the director of acquisition and sourcing management at the GAO, states that two-thirds of the U.S. Coast Guard’s acquisition will be mainly prioritized by the OPC starting from 2018 to 2032 [8]. Admiral Zukunft, the previous Commandant of the Coast Guard, stated that the construction of the OPC is the biggest priority at the moment. Unfortunately, this prioritization has forced the Coast Guard to neglect the research and development of many new technologies, such as the implementation of autonomous UAVs. Instead, the service has been adapting commercially available products to fit the Coast Guard’s specific needs.

The Roboboat competition problem is an ideal venue for our group to test different techniques relating to the Coast Guard’s current capability gaps. Taking off from and landing a UAV onto the surface vessel poses many of the same challenges of landing on a Coast Guard cutter. Using an onboard camera to identify specific features in the course will rely on the same computer vision techniques used to identify people or vessels in distress in a large body of water. Controlling our drone, accounting for the vehicles kinematics, and planning search algorithms will require our group to address many of the challenges faced by researchers implementing drones to Coast Guard search and rescue operations. While formal requirements of our capstone originate from the Roboboat competitions, the product of our research will be directly transferable to the implementation of UAVs in Coast Guard missions in a time when Coast Guard research and development funding is particularly limited.

References

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