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Survey of Autonomous Drone Hangars– Opportunities and Challenges for Maritime Platforms

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Abstract

Over the last 5 years multi-rotor drones have taken off as completely autonomous vehicles able to patrol, photograph, and inspect large campuses and infrastructure. Drone hangars allow drones to complete the entire mission cycle autonomously. Drones paired with a hangar can be left in place to periodically patrol a perimeter or can act as a station which drones can be dispatched to carry out missions remotely. Separately, advancements in image recognition and drone flight computers make it possible for multi-rotor drones to land on moving targets. Combining these two technologies would allow drones to operate autonomously from vessels. Applications include automating hull inspections, performing logistics tasks, or creating mobile drone carriers. Drone hangars on moving platforms have yet to be implemented but are feasible with current technology.

Keywords: Drones, Ship Landing, Defence

1 Introduction

Multi-rotor drones have been used for photography and remote inspection for two decades, but until 2017, they were either piloted or supervised with direct line of sight (Ball, 2017). Recently, there was a move towards compact portable launchpads or bases for use with drones, i.e., drone hangers. The first release of drone hangars was in 2017 which can store and charge drones allowing them to semi-autonomously complete missions. With drone hangars, tasks like structural inspection, terrain mapping, or security can be done with minimal human involvement. Instead of having a security team patrol a fence, a UAV can periodically survey the area and trigger an alert if certain criteria are met.

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UAVs can also be used to spot fires or other equipment malfunctions in industrial areas. As long as the drones can recharge and upload data autonomously, a drone-in-a-box (drone hanger) can be set to do tasks for months on end without any human interaction, limited only by maintenance cycles requiring human intervention.

One of the major engineering challenges for autonomous drones is landing without human control in a range of variable conditions. In 2022, researchers released a methodology for visual based landings using cameras that give multi-rotor drones the ability to land on moving targets (Keller & Ben-Moshe, 2022). This opens the door to develop new drone hangars which can be positioned on mobile platforms such as trucks or boats. This paper seeks to survey the feasibility, opportunities, and challenges associated with deploying drone hangers on moving maritime platforms.

2 Materials And Methods

To complete this survey, a review was conducted into the current abilities of multi-rotor drones, landing algorithms, and industry solutions for autonomous drone platforms. Drone specifications were taken from company websites and promotional material. Information about maritime drone use and landing algorithms are from recent papers and journal articles. These areas provide an idea of the current state of autonomous drone flight, as well as the requirements that must be met to operate on a maritime platform. Following the literature review is a discussion on the feasibility and challenges of such an implementation.

3 Literature Review

3.1 Current Drone Capabilities

Multi-rotor drones are available at a variety of price points and capability levels. Some drones are made for specific industries such as agriculture or manufacturing, others are designed specifically to maximise a certain aspect of drone flight such as top speed or payload capacity. With the harsh nature of ocean environments and variety of tasks required, a high-end enterprise drone would be required for maritime environments. Table 1 below shows an example comparison of commercially available drones.

Table 1: Enterprise Drone Comparison

Model	Speed (m/s)	Payload (kg)	Flight Time (min)	Hangar	Price(AUD)
DJI Matrice 300 RTK	23	2.3	55	No	$20,000
Teledyne FLIR SIRAS	18	0	31	No	$14,000
Freefly Alta X	26	15	41	No	$26,800
Dronehub.ai	20	5	45	Yes	Not listed

Note: From (DJI M300 RTK Specs, 2021), (Teledyne FLIR siras UAS System, 2023), (Introducing alta X. Freefly Systems, 2023), (Dronehub.ai, 2021)

3.2 Landing Algorithms

Autonomous landing is a current area of study. Currently, most consumer drones have a "return home" feature where they will navigate to where they took off from using GPS, and then land vertically. This feature is quite basic and is suitable for landing on stationary targets in stable environmental conditions. In 2022, researchers were able to land drones using a 'slide landing' technique (Keller & Ben-Moshe, 2022). This allows multi-rotor drones to land on moving targets and at angles between 10 and 60 degrees. These drones need to be able to detect a landing pad and then align themselves for a landing. Usually, the landing pad is marked with an ArUco marker, which is a black and white pixelated image that is easily recognized by image processing software. Slide landing is the only technique that multi-rotor drones can use to land on moving targets and will be critical for landing on vessels in motion. All drones have the physical capabilities to perform slide landings. Software is the limiting factor as this type of landing requires both programmable drone flight and image recognition, two recent developments in UAV technology. The company UAV Navigation offers an autopilot that can land on a vehicle moving at up to 30km/h, however it is packaged as an avionics box that is suitable for enterprise level multi-rotor drones.

3.3 Current Industry Solutions

For drones to operate autonomously, they must be able to land, dock, charge, transfer data, and launch without any human interaction. The common solution to these requirements is a drone hangar, or a “drone-in-a-box”.

Several drone hangars are made by commercially available such as Dronehub (Figure 1), Skycharge, Percepto, and Heisha (Figure 2). The solutions currently on the market broadly fit into two categories: hangars designed to be exclusively compatible with a specific type of drone and often sold as a set, and more universally compatible hangers that can be used with any drone. In the latter category, additional landing gear is required to interface with and charge at the hangar and must be fitted to the drone itself. Hangars and drones that are designed as a set have these interfacing features integrated into their design.

Figure 1: Photo of Drone Hub Device (Autonomous Drones in a Box)

Currently all purchasable hangars are intended to be stationary. However, most could feasibly be used on moving platforms as long as the drone is able to accurately align and land on the pad. As a typical example of the deck space required, the Sensyn Drone Hub is for larger enterprise drones and has a footprint of 1.89 m x 1.77 m.

Figure 2: Heisha Landing Pad with Landing Gear Highlighted
Source: (The Future of Autonomous Drone Operation, 2022)

3.4 Current maritime applications

Drones are currently being used in the cargo shipping industry to inspect hulls externally, as well as cargo holds internally. Additionally, emergency services use drones in search and rescue operations, and have been used to drop floatation devices to people at sea (What is a maritime drone?, n.d.). Common models currently used in maritime industry are the DJI Matrice 3 RTK, Teledyne FLIR SIRAS, and Dronehub.ai. Currently, the aforementioned applications are all carried out by a human pilot.

Figure 3: Volaris V-line Boat Mode (Vehicle mode, n.d.) Using a Drone for Improved Visual Monitoring

The company Volaris offers a product called V-line boat mode that uses a tethered DJI Mavic 2 drone to fly up and act as a lookout (Figure 3). The drone can take-off and land autonomously and is powered through the tether (Vehicle mode, n.d.). Currently, this is the only system with automated take-off and landing. The tether allows the drone to stay in the air without draining the battery and makes it easier to land autonomously but limits the drone to only acting as a lookout.

4 Results and Discussion

4.1 Opportunities

The current uses of drones in the maritime industry, such as hull inspection, rescue operations, and birds-eye-view could be further automated through the adoption of drone hangars that enable autonomous landing and charging. This technology could significantly decrease manpower requirements for many offshore tasks, in turn decreasing cost, reducing downtime and improving operational efficiency. As drones can cover large swathes of sea, they could speed up search and rescue operations while decreasing manpower. The use of drones in surveillance offers a cheaper and greener alternative to patrol boats and could also be used to automate inspection of offshore wind or oil rigs. The technology is also being considered for the testing of electronics communication systems and for use in testing sulfur emissions compliance (Frederiksen & Knudson, 2018). In all of these applications, the full benefits of automation can only be realized if the drone is able to operate autonomously/remotely for extended periods of time without human assistance; a capability provided by the drone hangar concept.

A dedicated drone carrier vessel could send drones in all directions expanding search and rescue operations allowing a single human to monitor several video feeds at once rather than have several humans pilot drones. Such a vessel could also be used by coast guards to create a virtual ocean border across vast stretches of ocean or could be used by Navies to fly drones into seaside cities for surveillance. A dedicated drone carrier could use a modified hanger concept with a landing pad that would stock the drone in a rack or magazine and have the potential to send out a swarm of drones at once.

Multi-rotor drones also have a use case for transporting small parcels from ship to ship, or from ship to shore as the vessel would not need to stop or pull into port. As drones have low payloads, this would be limited to light items such as medicine, cash, spare parts, documents (Krystosik-Gromadzińska, 2021) or electronics.

4.2 Challenges

The main challenge for implementing drone hangars on maritime vessels is landing. Landing on moving platforms for multi-rotor drones is new, while it has been demonstrated to work, the limits for vessel speed and sea roughness during landings are not well defined. It is also not known how much landing area is required to perform these landings. In lab conditions and at low speeds, the drones can land on 500mm x 500mm platforms (Keller & Ben-Moshe, 2022). But higher speeds could have a higher landing zone requirement. The landing ability is ultimately determined by the specific drone model, and at this point in time, slide landings have only been performed using consumer level drones. Enterprise level drones, which would likely be used for maritime applications, have higher specifications and capabilities, and would presumably perform better, but the specifics are not yet known. The challenge of landing is further exacerbated by high wind speeds. A drone like the Matrice 300 RTK can fly at 23 m/s and in winds up to 15 m/s, but in a 15 m/s headwind the drone would only be able to fly at 8 m/s and may not be able to keep up with the moving vessel to accurately land.

Another possible challenge is pitch and roll. As slide landings use visual information from the camera, the most important aspect to landing is tracking the landing zone. As pitch and roll do not visually obscure the landing zone, the currently existing landing methodology will be able to handle some degree of pitch and roll, but the limits are unknown. Hangars may need to be gyroscopically stabilized for take-offs and landings, if the pitch and roll of maritime platforms exceed the control resolution of the drones. Current models are designed to be used on land and extra care may be needed to secure the drone in the hanger at sea. Additionally, at sea the hangar would also need to be designed to prevent water ingress.

Additionally, in areas of high drone traffic, a traffic management system needs to be developed (Muhammad & Gregersen, 2022). As drones will be operating beyond visual line of sight, a base station will be required to coordinate with each other to route traffic and efficiently assign tasks. Technical solutions have already been recommended for port areas using 5G towers (Muhammad & Gregersen, 2022), a dedicated drone vessels would require an equivalent for operating multiple drones at sea.

Lastly, drones require periodic inspection and maintenance. For example, the DJI Matrice 3 RTK requires routine maintenance every 200 flight hours or 6 months (Matrice 300 RTK Maintenance Manual, 2020). This limits the amount of time that the drone can act autonomously. Most drone user manuals recommend visual inspections before and after every flight, but the requirements are often quite basic such as making sure the propellers are intact. As user manuals are typically written for piloted flight, organisations may need to develop their own inspection guidelines for drones that are operated autonomously. Some aspects of maintenance such as visual inspections could reasonably be done remotely through cameras or remote monitoring.

5 Conclusion

It will not be long before drone hangars can be mounted on maritime vessels. Autonomous landing on moving platforms is still in the experimental phase and the upper limit of landing speed and landing area requirements are not yet known. Additionally, even the enterprise level drones will struggle to fly in harsh weather and may have trouble landing into headwinds. Despite this, the opportunities far outweigh the challenges as autonomous drones will drastically reduce workforce requirements for tasks such as search and rescue and open the door to creating dedicated drone carriers with new uses. It won't be long until drone carriers become a vital part of coast guards and navies, and that general-purpose drones become a standard feature of all large vessels.

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