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A Literary Review on the Current State of Drone Technology in Regard to Conservation

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Abstract

This paper will review the types and use of unmanned aerial vehicles (UAVs) in conservation. Drones are being used as the preferred method of monitoring terrestrial and aquatic wildlife in difficult areas, thanks to the low price and efficiency that these tools offer. The paper discusses the three main types of drones: fixed-wing, rotary-wing, and hybrid. Fixed-wing drones are best suited for general surveillance of large areas and long-distance flights, while rotary-wing drones are small, light, and maneuverable, making them ideal for tasks such as photography, filmography, inspection, and surveillance. Hybrid drones are more complex, combining fixed and rotary wings or rotors. The paper also explores the potential benefits of adding solar panels to drones to improve their energy efficiency.

Multiple instances of the successful use of drones in the field were documented, including drones being used to identify objects in water, land, or air. Advanced machine learning algorithms were proven to be highly effective in identifying targets for military, conservation, and other purposes. The optimal placement of docking stations for aerial drones was discussed, and how they could be found using a new algorithm, back-and-forth-k-opt simulated annealing (BFKSA), was also discussed.

Overall, drones provide a cost-effective and efficient way to monitor and protect wildlife, making them an important tool for conservationists.

1. Introduction

In the modern day, drones are being used in increasingly many circumstances -- from pest control to military use and, recently, wildlife conservation -- due to the implementation of new technologies onto these platforms. Drones like unmanned aerial vehicles (UAVs) and autonomous underwater vehicles (AUVs) provide many benefits over traditional monitoring methods for detecting poaching vessels and observing species in the wild. One of the primary reasons that drones are preferred to traditional monitoring methods is the cost-effective nature of the technology. UAVs, for example, tend to be fast, small, light, and agile when compared to the heavy and large manually controlled aerial alternatives. This can allow UAVs to access difficult-to-reach terrain (Hassanalian & Abdelkefi, 2017). This saves the need for direct human effort to oversee large conservation areas, while saving money due to the low cost of UAVs.

2. Research Methods

The search engine utilized for finding the sources in this paper was Google Scholar, a publicly accessible extension of the Google search engine that will show scholarly articles that best suit a certain search. The intention of the research was to gather as many sources discussing the current state of drone technology. This research was conducted from April 17, 2023 to May 3, 2023.

The following search phrases used were: “aerial drones for ship detection”; “tools for detecting ships from aerial platforms”; “advancements in aerial drone technology”; “types of underwater drones”; “underwater drones for surveillance”; “designs of underwater drones”; “atlan drones tracking illegal poaching vessels”; “underwater drones for conservation”; “use of ‘underwater’ drones for poaching”; “thermal for detecting surface ships”; “infrared for detecting surface sips”; “tools to identify surface ships”; “using LIDAR to detect surface ships”; “underwater drones for monitoring wildlife”; “silver sky aircraft”; “silver sky”; “aerial vs underwater drones in conservation”;

In addition to using search phrases, many of the articles mentioned cited other useful articles directly in their references, thus leading to relevant documentation.

3. Types of Aerial Drones

There are a wide variety of UAVs all with different uses, functionality, and price (Hassanlalian & Abdelkefi, 2017; Mohsan et al, 2023). The main types of UAVs are fixed wing, rotary wing, and hybrid -- a much newer type (Hassanlalian & Abdelkefi, 2017; Mohsan et al., 2023).

3.1 Fixed Wing Drones

Fixed-wing drones have the traditional plane shape with broad wings and a symmetrical shape going down the body of the plane ending with a tail and rudder. These tend to have a larger size and weight when compared to the other models, but make up for it with efficient flight performance and the capabilities for long-distance flights (Mohsan et al., 2023). This style would be best suited for tasks that require general surveillance of large areas, and a fast top flight speed (Hassanlalian & Abdelkefi, 2017; Mohsan et al., 2023). Fixed-wing drones, however, also require strict take-off and landing conditions, such as being thrown or taking off from an appropriately sized runway (Mohsan et al., 2023). This drone model also tends to be more expensive because of the larger size and more powerful equipment (Mohsan et al, 2023).

Unlike other types of drones, fixed-wing drones have the potential to be fitted with solar panels for mid-flight charging with a simple addition (Hassanlalian et al., 2014). This is all due to the large surface area of the platform from the wings, long body, and tail -- compared to most other drone types. The addition of solar panels was cited by Hassanlalian (2014) to improve the energy efficiency of the drone by up to 30%. In 2021, a team of Chinese researchers achieved a 22.5% flight energy efficiency improvement using custom-built wiring and lightweight solar panels on a fixed-wing drone (Chu et al., 2021). These modifications are only effective in proper sunny weather, specifically sunny weather that exceeds 700 W/m^2 of solar radiation (Chu et al., 2021; Hassanlalian et al., 2014). This may replace purely battery-powered drones in the future, but as it stands, most drones use lithium batteries for their light weight and ease of use (Hassanlalian et al., 2014).

3.2 Rotary Wing

There are two main types of rotary-wing drones (Mohsan et al., 2023). The single rotor drones (helicopters) tend to be larger in size, difficult to build and operate, and more expensive while also being somewhat unstable in the air (Mohsan et al., 2023). This makes single-rotor drones a much less commonly used style than multi-rotor, fixed-wing, or hybrid models (Hassanlalian & Abdelkefi, 2017; Mohsan et al. 2023).

Multi-rotor drones, on the other hand have many more benefits to them than single-rotor drones. Multi-rotor UAVs are typically small, light, and maneuverable while having the ability to hover in place if needed (Hassanlalian & Abdelkefi, 2017; Mohsan et al., 2023). This type is the cheapest of all the other common types of drones, costing around $3 - $50k for a single drone with all of the equipment included, according to a study by Mohsan and his team (Mohsan et al., 2023). This makes it very commonly used for many applications. Photography, filmography, inspection, and surveillance are all tasks that multi-rotor drones are well equipped for (Mohsan et al., 2023). These come with the downside of having a poor flight time and a smaller payload (Mohsan et al., 2023). This design does allow for the autonomous landing of the drone at charging stations, making fully autonomous swarms of drones possible.

3.3 Hybrid

A hybrid drone model is a bit more complex than the fixed wing or rotary wing type drone. This style leaves the ground with one type of flight, and flies with another, which is accomplished in many ways. The two most common types of hybrid drones are tilt-rotor and tilt-wing

(Hassanlalian & Abdelkefi, 2017). Tilt-rotor drones have the fixed wings, body, and tail of a standard fixed-wing drone but with the addition of rotors that can point up for take-off and tilt forward 90 degrees for cruising (Hassanlalian & Abdelkefi, 2017). This style is known to be very stable in hover flight (Hassanlalian & Abdelkefi, 2017). Tilt-wing drones are very similar to tilt-rotor drones, except instead of tilting only the rotor, the entire wing is kept vertical for take-off with the propellers pointed up and then tilted forward 90 degrees for cruising (Hassanlalian & Abdelkefi, 2017). This style was very effective for long distance cruising (Hassanlalian & Abdelkefi, 2017).

Although these drones are very functional and can do most things any other drone type can do, they come with a higher cost and are less efficient at long-range flying than fixed-wing drones, and are less efficient than multi-rotor drones at hovering (Hassanlalian & Abdelkefi, 2017). Because of this, there aren't too many real-world examples of these drones being used for tasks.

4. Functionality of Aerial Drones in the Field

While fixed-wing, single-rotor, and hybrid drones are useful in their own right, a multi-rotor drone is usually preferred for conservation efforts. With poaching still being a common problem worldwide, many organizations have turned to cheap multi-rotor drones to protect wildlife. In 2015, a team of researchers in Africa successfully designed a quadcopter drone that can not only track individual animals in their natural habitat without disturbing them, but also had the capability of using facial recognition to build a database of potential poachers spotted around the target animal (Olivares-Mendez, 2015). The drones were even demonstrated to follow and report the vehicles that the poachers used, and to land completely autonomously (Olivares-Mendez, 2015). These drones, however, were limited by the quality of the camera available and couldn't detect faces or animals past a somewhat short distance (Olivares-Mendez, 2015). This team did prove the potential for a fully autonomous drone to be used in a swarm capacity to assist in wildlife conservation (Olivares-Mendez, 2015).

For marine environments, aerial drones continue to be proven effective for both detecting near-surface animals and poaching vessels. In 2021, a team of shark researchers published their findings on using aerial and underwater drones to monitor sharks through RGB cameras (Butcher et al., 2021). In this paper, it was found that advancements in gimbal and telemetry technology allowed for greatly improved target acquisition, while thermal and infrared cameras have promise but are strictly limited in use to creatures breaching the surface (Butcher et al., 2021). Aerial drones were successfully used to find that hammerhead sharks will swim with blacktip sharks casually from a distance and then swim rapidly to catch and consume the smaller blacktip sharks (Butcher et al. 2021).

4.1 Machine Learning for UAV Object Recognition

Recently, many strides have been made to automate the processes of identifying vessels on the water. In 2022, a research team created a machine learning model that can detect surface ships from an image with 99.5% accuracy (Paiano et al., 2022). This model was trained in YOLOv4 using a custom-built data set that featured boats in various contexts, such as a boat in dock, in open water, with calm water vs. water with waves, different types of boats, etc. (Paiano et al., 2022). While this paper didn't utilize a drone necessarily to test the machine learning algorithm, it still shows the promise and utility of using machine learning to automate the process of identifying objects in the ocean via an airborne platform.

Aerial drones have also proven effective in identifying fast-moving airborne targets. A team in the U.S. managed to build an aerial drone that was capable of finding a target drone and was able to follow the target drone at high speeds through a small but effective YOLOv3 algorithm (Wyder et al., 2019). The algorithm achieved an overall accuracy of 77% when given images at 8fps with potential motion blur and obstructions (Wyder et al., 2019). The data set this team used only had 58,000 images of the target drone, which made this particular case very impressive (Wyder et al., 2019). The code and images used by this team are publicly available in their repository https://osf.io/n9q78/.

Another team was able to create a similar drone experiment where an aerial drone was built to detect and follow another aerial drone from up to less than a hundred meters away (Opromolla et al., 2018). This test was specifically to assist drones in navigating through regions of poor signal using machine learning to follow a guide drone to its intended target (Opromolla et al., 2018). They achieved a mean accuracy ranging from 85% to 95%, by utilizing their machine learning algorithm that adjusts for template matching and morphological filtering, creating an overall highly accurate model (Opromolla et al., 2018).

4.2 Current State of Sensors

However, the types of sensors used on aerial drones to detect surface vessels tend to be RGB cameras as opposed to any LIDAR, Thermal, Infrared, or Radar being used. There didn't seem to be any journal article describing the use or benefits of using any sensor that wasn't RGB for detecting surface vessels. This is likely a field of interest that could use some more study as RGB cameras are heavily limited by the time of day, while other sensors are not.

4.3 Docking Stations

A docking station is a structure designed to catch or allow for the landing of UAVs, usually multirotor drones, on or within it. They often allow for charging capabilities that can extend the flight range of a drone and are a valuable asset in autonomous drone swarms. In 2020, a team of researchers wanted to test the optimal layout of docking stations around a farm for aerial surveillance drones to cover the whole area of the farm with the minimum amount of docking stations for the drones to autonomously land and charge at (Fendji et al., 2020). Multiple algorithms were tested, including coverage path planning, back and forth, Hilbert, and a new algorithm proposed by the team called back-and-forth-k-opt simulated annealing (BFKSA) (Fendji et al., 2020). Over 20 different topologies and environmental conditions were tested with BFKSA being proven to be the most effective algorithm for extending the coverage of an aerial drone using the fewest number of docking stations (Fendji et al., 2020).

5 Underwater Drones and Their Uses

For the purposes of monitoring underwater creatures and vehicles (and to a lesser extent monitoring surface objects), there are few better alternatives than underwater drones. There are two main types of underwater drones, AUVs and ROVs (Butcher et al., 2021). AUVs are fully disconnected from any other vessel or building, and typically operate with acoustic sensors for marine monitoring purposes (Butcher et al., 2021). Multiple studies have been conducted using AUVs where machine learning algorithms have been effectively used to document shark species using acoustic sensors on large drones to learn behaviors and population numbers of species (Butcher et al., 2021). ROVs on the other hand are connected to another vessel or structure and receive power and communications through a tether (Butcher et al., 2021). This makes their functionality limited to short range operations, although they will not have as many communication issues that result from poor weather in the water (Butcher et al., 2021).

In India, AUVs are being developed to protect the entire coast from foreign submarines (Yadaiah et al., 2021). These drones are being used for military purposes, so they likely have a higher budget than most conservation drones, but they still demonstrate the potential of using a network of underwater drones effectively for communication (Yadaiah et al., 2021). In this case, the drones are connected to the internet and can even connect to the user's smart phone through an app (Yadaiah et al., 2021). When the machine learning algorithms guiding the on-board LIDAR sensors detect a potential foreign submarine in a restricted zone, the user would receive an emergency notification (Yadaiah et al., 2021). The paper describes that LIDAR sensors are cheaper and more effective than traditional sonar sensors for this scenario (Yadaiah et al., 2021).

An experiment that used aerial and marine drones concluded that both UAVs and AUVs effectively detected surface litter in marine environments (Escobar-Sanchez et al., 2022). While aerial drones were generally more effective, it seemed that both types of drones had different niches in detecting surface litter, meaning that UAVs could spot litter that AUVs couldn't detect and vice versa (Escobar-Sanchez et al., 2022). It is also worth noting that both types of drones working together were far more efficient and accurate for litter detection when compared to a manned vehicle control group that was also being tested (Escobar-Sanchez et al., 2022).

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