Literature Review on Drones Used in the Surveillance Field

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***Abstract*— The current study reviews the available literature about UAVs employed in the surveillance field for indoor and outdoor spaces. At first, we differentiated between HTA and LTA. After a first analysis, we compared the two categories, and we proposed active solutions. In our opinion, it would be possible to put them into practice by implementing a system which would operate both copter drones and blimps. These, in fact, present advantages and disadvantages which overcome one another, giving the possibility of such dual systems. This study is developed inside a broader analysis on how to provide the right level of security of an automated port that would rely on an autonomous security system.**

***Index Terms*— Blimps, drones, UAV, autonomous security, surveillance**

I. Introduction

CONSIDERING the misleading outcome of human reaction to specific issues, nowadays, it is possible to overcome false alarms with newly developed tools. The efficiency of the system and the human factor are the main elements impacting surveillance. In this work, we want to review the researches and applications of UAVs on surveillance in different scenarios. Surprisingly, during the research phase of our project, the literature regarding the application of UAVs in the surveillance field is still minimal. We found very little, especially about the part concerning the security of the infrastructure. However, we found how UAVs have already been studied in safety, especially regarding their employment in scenarios of disasters, for example, earthquakes. According to their lifting power, UAVs can be divided into two categories: Heavier-Than-Air (HTA) and Lighter-Than-Air (LTA). Within the first category belong drones, which we discuss in the first part of our article. In the second part of the paper, we will talk about airships, more commonly called blimps, which belong to the LTA category. It has been crucial for us to differentiate the two categories. If literature about UAVs used in the security field is insufficient, the literature about these two subcategories is even meagre. From what we could understand, the will of employing both copter drones and blimps is widely spread. The main advantage that many studies highlight is that the efficiency of such technology is well implemented with sensors. Finally, in the third part, we compare two surveillance methods to use UAVs to provide a given level of autonomous security for outdoor and indoor environments.

The next step for us as researchers of the University of Genoa is to implement said technology in the security sector of the port area. We are currently developing a simulation with AnyLogic and studying to implement this project within the Internet of Things system properly.

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II. Drones

Nowadays, it is possible to acquire a drone in effortless ways or even possible to build one. These drones are used as a hobby and as something not very complicated from a technical point of view. When we start thinking about drones as means for surveillance of specific environments, we must depict a different kind of technology, mainly related to the framework of the fourth industrial revolution. In the literature, it is possible to find studies about the employment of UAVs for protection, surveillance, and, in some instances, rescue. The case about drones used in the surveillance field has been rarely studied, so we could not find many references about this type of application. Those studies let us understand the state of the art of drones employed in different fields and, most importantly, about the issues recorded, to which we are willing to propose active solutions.

Anyone can purchase a drone (a concept with many different meanings) nowadays, and it is also challenging to understand the intentions for which the people may or may not use the drone. People need special licenses to drive drones, mainly because, nowadays, many urban areas have the so-called "no flight zones" to avoid interference with specific operations. Nevertheless, even if a drone is used within the constraints given by the law, this one may still not be safe. Remotely piloted vehicles can be employed on many occasions. It has been then necessary to study how to identify such objects' types and intentions [2]. After testing under different scenarios to increase the difficulty of recognition and improving the software, the scientists obtained an astonishing rate of protection of 96%. This research, and other studies, put ourselves under the optic that it will always need a system of detection and protection from external agents in a scenario of infrastructure surveillance.

Drones have been at first employed in the military field and only after they became available to civilians. The improvements related to the employment of drones for surveillance also consider the velocity of response and autonomy. Drones started to be chosen in the commercial business sectors as cost- and time-effective tools [13]. A UAV can also be employed to transport small objects and packages without requiring too much computational energy by setting up waypoints that the drone would be able to follow [3]. It is then possible to develop a surveillance system employing drones, but this would need to be based on cognitive IoT [4]. This concept must be implemented for a better cloud-based system where all the elements must communicate and share information.

A studied problem related to the ability of drones to object recognition and tracking is the delay between recognising and tracking moving objects. This concept is essential in the scenario of employing such technology in the surveillance system of an industry. This concept can also be applied to recognising that an object is not at its place and sending an input recording the necessity of putting the object at its place. The most effective solution to such an issue is to give the drone the capability to perform recognition without the support of the control centre. The experiment conducted by Kim et al. [10] brought some reliable results for their dynamic computation offloading scheme for drone-based mobile surveillance systems. In 2017 it was proposed a new technology called YOLO9000 [14]. It was an improvement in the field of object recognition technology. As an improved version of YOLOv2, it was developed to optimise detection and classification jointly, improved then subsequently, in terms of speed, by YOLOv3 [15]. We thought about a question that the article was not thinking much about the biggest problem of drones: battery consumption. Such improvements on a drone's computational capabilities for sure would lead to energy-related issues that have not been discussed in such a study.

It is well understood the eventual effectiveness of the employment of drones for search and rescue operations, but this requires the development of very efficient algorithms for autonomous drone surveillance. The employment of deep learning approaches is necessary. Drones would be employed for scanning a specific area and understanding where help is required. The obstacle encountered for such an aim is the amount of data needed for training. In the case of SAR operations, the drones would need to recognise small gestures (like a waving hand asking for help, moving legs under a structure) from the operators to understand the number of people involved in the accident and, eventually, asses their conditions [11]. Nowadays, the issue is that there is a limited amount of studies about action recognition and human detection on aerial images. Therefore, we need to develop an algorithm to scan a particular area and recognise specific actions and objects for surveillance purposes.

In the scenario of an industrial area, we have to consider the complexity of the system. This factor has an essential role in understanding the resources needed to minimise the human factor and, consequently, increase the system's efficiency. The complete automation of drones is the most concerning issue to face for indoor navigation [21]. When thinking about drones for surveillance, it is crucial to implement them with sensors such as cameras, ultrasound, LIDAR or LEDDAR, etc. Ensure a safe flight in a restricted environment has been understood as the main problem. For outdoor spaces, the orientation issues are solved through the joint employment of GPS and Glonass (for orientation and positioning) and Real-Time Kinematic systems (for obstacles and objective recognition) [7]. Relying on this technology for localisation and navigation, many are the tasks that UAVs can perform. When indoors, it is necessary to find a way to determine the position and of the reference points. For this purpose, it is then possible to implement drones within the framework of IoT tools for fast verification and identification. To carry on operations in indoor environments, it is necessary then to implement the drones with different systems such as autonomous sensors for stability and floating, gyroscopes (as a combination of microelectronics and mechanics), accelerometers, magnetometers, piezoelectric barometers, ultrasonic distance meters, stereoscopic cameras, LEDDAR to determine the distance of an object. It has been theorised [8] how the techniques regarding indoor localisation can be branched into three primary categories:

Wave characteristics and propagation through diverse media do not give the drone an accurate position (with errors in the order of 5-9 cm). Therefore, it is essential to avoid any collision between this and any element of the indoor facility

. For this, vision-based/image-based localisation supports computer vision to map items in the global coordinate system. However, it is a technology that has not been well studied in a dynamic indoor environment.

In an inertial navigation system, localisation is possible if given an initial location and different motion sensors. However, the employment of inertia measurement units (IMU) was not practical due to the possibility of creating hazards, such as loss of control and subsequent collision with objects.

A proposed solution from previous studies, referring to the second category studied by Ibrahim & Moselhi [8], consists of AprilTags and coordinates known a priori through 3D BIM [12]. This solution aims at increasing the autonomy of UAVs. This suggested method is cheaper in terms of cost and resources than the nowadays known solutions regarding the employment of wireless networks, UWB, or vision-based positioning cameras. The employment of such tags is very relevant, but they seem to have issues related to the distance between the tag and the drones for effective communication and the localisation during the operations of take-off and landing of the UAVs.

The potential of this growing technology is nowadays limited by the power of the batteries used. Therefore, it is necessary to develop a system that would extend the duration of the performance of aerial drones. The military scenario proposed by Williams & Yakimenko [22] defines many ideas which could be implemented: hydrogen fuel cells, solar-powered drones, laser beam in-flight recharging, etc. If the drone must return to a base station, it is needed to save (economically and time speaking) where possible by making this process automated. In this case, charging the battery can be considered an option, but processes like battery swapping can be considered. Williams & Yakimenko developed a new concept to complete a mission. To complete the mission, Williams & Yakimenko theorised to use 3 (or 4, depending on the necessity) drones that would communicate and work, swapping between one another when the battery falls below a certain threshold. In this way, the loss of data would be minimised, and the mission would be completed with a minimal computational effort from each drone.

III. Blimps

Another type of surveillance equipment we would like to consider is blimps. Blimps refer to a non-rigid LTA motorised airship, which can be human-crewed or unmanned. They have some advantages compared to other aircraft types, such as structure simplicity, low acoustic noise level, high payload-to-weight ratio, long durability in air, low energy consumption, and vertical take-off and landing ability.

Traditionally, a blimp robot is a hull shell filled with a lighter gas, a propeller, and a nacelle, which holds necessary equipment, such as IMU, compass, camera, RF communication module, data logger, propulsion system and battery, etc.

Blimps can be easily purchased or even built. When calculating the lifting force of a blimp, it is necessary to consider its source: static, dynamic, or powered. In our work, we want to use static lifting force using gases. In selecting the necessary gas, its lifting force and characteristics should be considered [5]. We cannot use hydrogen and methane because they have the property of ignition, which cannot be used since we conduct the study to ensure the safe operation of the port. Hot air has three times less lifting power than other gases (3.14 N/m^3, when others exceed 10). So for our future project, we will choose the most expensive but commercially available, low-flammability gas, helium, by pumping air into the housing before checking for leaks.

The study of Ganesh [5] offers a methodology for calculating the static lift of the blimp, surface area and projection area, motion, and some structural parameters. The design has been generated in CATIA V5 as per the specification and dimensions obtained by the authors. The analysis for estimating the drag and pressure distribution over the blimp was performed in Ansys Fluent.

Some researchers [9] considered the motion of a blimp robot consisting of two hulls, which increases the airship's carrying capacity. The paper also noted that, when calculating the lifting power of an airship, it is necessary to consider the temperature and pressure of the environment since the compressibility of helium, the most commonly used gas, depends on these parameters of the environment. One of the most frequent problems of blimp control is a significant deviation from the course due to the influence of wind speed. The research showed that the airship deviated from the course after several meters for indoor and outdoor operations, but the deviation values decreased when using closed-loop control. Therefore, for the scenario we are studying, it is necessary to consider the influence of wind speed and its direction in the port and use closed-loop airship control.

Nowadays, UAV technology is used by civilians also for local safety reasons. An example of the employment of drones for safety is represented by Gorkin III et al.[6]. To keep a healthy marine ecosystem in Australia, agencies started developing software to teach drones how to recognise an eventual threat for beach-goers (such as sharks, stingrays, etc.) and share the data through smart-wearable devices and phones connected to the system. However, for how much drones were presented as a well-tested liability, the main issues are still persistent: limited battery life, the need for pilot training, equipment expertise, and limited flight areas per air safety regulations, etc.

Another study [1] was conducted based on continuous wildlife monitoring. This feature would provide visitors with information about the state of fauna and simplify the authorities' work to ensure safety on beaches. The research was carried out using blimps as an aerial platform. In their study, the authors pointed out the advantages of using blimps over other types of aerial survey devices to observe ecosystems, such as silence and remoteness, at least 8 hours of observation with no need of a recharge, zero licensing, and minimal training, so it can be deployed without reference to the aviation authority and without needing a drone pilot. The study explained that due to the disadvantages of specific systems, from a height of 70 m, it was impossible to distinguish animal species, indicating the need to improve camera parameters (10x optical zoom, Tarot Peeper). In the study, the blimp was used only 70% of the prearranged time, as for the other 30% of days, the system could not be deployed due to environmental conditions (high winds of more than 40 km/h and rainfall).

Large-scale disasters, particularly earthquakes resulting in multiple casualties, occur around the world every year. Therefore, it has been studied how detecting people in the first 72 hours after a disaster can save their lives. For this purpose, airships are the most practical and suitable means of surveillance, thanks to their lower-sky availability, allowing high-quality 3D images. Saiki H. [16] proposed an autonomous blimp system with a robust flight control system in longitudinal motion using H-infinity control, which considers wind deflection. As a result of the research, applying control methods and dynamics of the airship's longitudinal motion considering the trim, the steady-state deviation about the altitude of the blimp was reduced.

Documented episodes show how drones are already used nowadays to identify individuals and surveillance (through the employment of thermal images, plate detectors, etc.). Evident reasons on how blimps show better performances than rotor drones are well explained, offering active solutions for inconveniences related to the fling and cost savings. Blimps are a means of surveillance that offers many advantages from a structural point of view, but drones, due to their reduced dimensions, represent a better choice when needed to perform operations in small environments [18]. Blimps also result in overcoming the battery-related problems previously highlighted for drones. Greater autonomy and durability in flight, energy efficiency, a low environmental impact, and the lack of large spaces for take-off and landing operations are features that would make blimps very efficient means during surveillance operations.

As technology for object recognition is available for drones, also blimps can be implemented with similar technology. However, developing a blimp for surveillance means recognising objects of the simplest geometric shapes was one of the first issues faced.

The first reliable attempt for autonomous communication between blimps and computers was conducted in 2018 by Shah et al.[17]. They considered the detection and tracking algorithm needed and the image procession concept.

By combining three algorithms ("edge detector," "canny operator," and "thresholding"), the authors came up with the following results: the thresholding algorithm is the simplest method of image segmentation, which creates a binary image consisting of black and white pixels, while canny use probability to find the error rate, improving the signal-to-noise ratio and allowing finding objects even when in noise condition. Thus, the authors developed an autonomous UAV for indoor surveillance and monitoring applications to recognise an object and display it in a designed graphical user interface.

In an enclosed environment, several blimp studies can be performed, including the calculation of aerodynamic performance. Fluid flow simulation programs help determine the drag coefficient, which, in turn, is used to determine the optimal streamlined profile of the blimp. In Van Asares et al. [19], to find the most aerodynamic blimp used indoors, several blimp profiles were simulated in SOLIDWORKS, which allows mass-size calculations to install components on the blimp body further. The authors used an Adafruit microcontroller in the ARDUINO programming language to control the blimp, which provides automatic manoeuvring through communication with servo drives. Using the Computational Fluid Dynamics method to determine the blimp design profile, the researchers were able to determine the drag coefficient and drag force experienced by the streamlined shape at three speeds (2 m/s, 1 m/s, and 0.5 m/s) and three length-to-diameter ratios (3, 4 and 5). In this way, the authors found the throttle level at which a balance of power and weight is achieved.

Furthermore, the researchers tested the selected shape under certain conditions of headwinds, from 0.5 to 2 m/s. They determined that, under the conditions mentioned above, the balloon can safely move in headwinds up to 2 m/s when it moves at more than 1 m/s. These results satisfy the conditions of the blimp hanging in the air.

Another study on the indoor application of a blimp robot [20] investigates the modelling and control of its motion and uses a platform developed by the authors to test the application of an indoor blimp on the example of industrial storage management. As we have noticed from other studies, the areas of most significant interest to researchers are maintaining stationarity, trajectory tracking, and especially developing a way to stabilise the blimp in the airspace to follow a given path. To this end, controllers are used to suppressing unknown uncertainty (robust control) and a dynamic system to estimate the unknown uncertainty, compensated by a closed-loop controller for estimation-based control.

In this paper, the authors divided the motion into vertical and horizontal motion, for each of which is controlled by a regulator with output feedback and perturbation compensation, which the authors of the study developed. The idea is to simplify the complex model by dividing it into two: a kinematic model, which considers North-East-Down directions of motion, and a dynamic model derived using the Newton-Euler equations. The authors then used the simplified model as a nominal model and augmented it with airflow perturbation conditions, after which a controller can be developed that evaluates and compensates for perturbations in real-time.

To control the blimp in space, the authors used the OptiTrack system, which captures and tracks the blimp in an enclosed test room, then solves the position and orientation of the blimp and transmits the result via Ethernet to the main PC. Thus, the motion of the blimp is realised in a closed loop. The blimp motion controller is implemented in Simulink software. The simulated "real system" is replaced by two interfaces: one receives a packet of blimp position information from OptiTrack, decodes the packet, and extracts the position information; the other packets the motor commands and sends them via the XBee wireless communication module to the STM32 onboard microcontroller of the blimp robot. Then, on the blimp robot control board, the XBee module receives the packet from the host computer, the microcontroller analyses the packet and controls the motors using PWM waves with the motor driver board. While the motors drive the blimp, the movement is always detected by the OptiTrack system, thus closing the loop of the system.

The work of Wang et al. is quite complete and valuable. Their experiments show the effectiveness of the developed controller for stabilising a point and following a trajectory in the presence of disturbances, and the results of practical tests coincide with the results of modelling. However, it is necessary to slightly expand the research to achieve the results we need, for example, to consider movements without assumptions to reduce the pitch angle when moving, develop general motion controllers without dividing it into vertical and horizontal, and add the use of a camera to achieve autonomy.

A critical issue analysed is the legislation behind the employment of drones, but because the scenario that we are considering is about the surveillance of private space, this is not an element that mainly concerns us.

IV. Comparison

TABLE I
COMPARISON BETWEEN DRONES AND BLIMPS CHARACTERISTICS

Characteristics	Drones	Blimps
Duration of flight	Between 20 and 30 minutes	Up to 8 hours
Reached heights	Maximum of 120 m	Maximum of 120 m without authorities permission
Cost	400€ to 20.000€ (from online research)	$5.000 to$10.000 (from literature)
Permission	Depending on the weight, they can fly or not over people up to a minimum distance of 150 m	Requires permission from aviation authorities for heights above 120 m and in no-fly zones
Required operator	Pilot with licence	Trained pilot.
Max speed	72 km/h	140 km/h
Risks	Collision with storage tools and humans	Minimal wounds during the phases of deployment and retrieval due to rope burns
Storage	Nominal requirements	Storage room

We needed to rely on the articles found in the articles without comparing such data with other sources on the internet for specific data. Meanwhile, for certain concepts, we considered EU Regulations 2019/947 and 2019/945 [23].

From a technical point of view, we understood that blimps have many advantages in surveillance. As we already mentioned, the application of UAVs in security and surveillance is not nowadays widely used and even studied. Very few have been the actual researches about the effectiveness and efficiency of the employment of such technology. From what we have collected, we got a clear idea of how both technologies present disadvantages and advantages that, if well-coordinated, can compensate one another. The short battery life of drones is compensated by the long flying time of blimps. The unavailability of blimps to navigate in small environments is supported by the reduced dimensions of drones and their high manoeuvrability. Furthermore, these are only two examples of how it would be possible to efficiently employ both technologies for high standard results.

The scenario proposed by our scientific advisor is related to the employment of UAVs for the security system of a new port area with outdoor and indoor environments. In the optic of Industry 4.0, we aim to connect the UAVs to a central computer and reduce the human factor in this way. During the debriefing phases of our study, we understood that it is possible to obtain different configurations of the drone-blimp system. The eventual difficulties during the lift-off phases of drones may be overcome with a first configuration. This one would have the blimp equipped to sustain the interchange of batteries proposed by Williams & Yakimenko [22]. If the quadcopters drones would also be equipped with a gliding system, the drones would be able to take advantage of an optimised propulsion system overcoming the technological limit of the battery. This system implies that the surveillance area cannot be too broad. In this case, the maintenance needed would be for sure one of the blimps. The autonomy can be improved with mechanical adjustments like double hulls. A second idea would be using the blimps for surveillance areas and localisation of situations and then drones for in-depth identification of the problem. In this case, the drones would charge the batteries on the ground and would not need, in theory, to interchange batteries to increase their autonomy.

V. Conclusion

We have aimed to provide a reliable literature review on UAVs used in the surveillance field. After understanding how meagre the amount of research developed until now, we decided how an optimal solution would be employing a combination of drones-blimps systems. This idea would be optimal because they would overcome the disadvantages of one another with each other's advantages (combining drones with high manoeuvrability but low battery life with blimps with long battery life and low manoeuvrability, for example). Further study will focus on developing both simulation and prototypes of the system, which we will find more reasons to be used in the scenario proposed by our scientific advisor.

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