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A kite balloon system for the monitoring of gatherings in open areas

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Abstract. To fight the diffusion of COVID-19, INAF-OAPA proposes an innovative prototype of a static aerial platform for observations from a certain quote. The technology, developed in the field of surveillance for public safety, environmental monitoring, such as illegal landfills, traffic, smog, fires and for precision agriculture, can be fruitfully migrated to other fields such as open areas monitoring, to identify large gatherings of people outdoors.

1. Introduction

In the last decades, new technological systems were introduced in the field of aerial monitoring. These devices allow rapid and large-scale detection of images and different parameters of interest (temperature, humidity, pressure) which can be useful to address issues both in urban and rural environments (Walsh et al. 2018). Sensors able to reveal specific environmental parameters can be installed onboard drones (UAV) or air-crafts, to acquire large scale images of a territory (Colomina et al. 2014; Korolkov et al. 2018). Many of these devices have found an additional application in contrasting the diffusion of the 2020 pandemic. Indeed, the COVID-19 emergency imposed strict though necessary limitations on personal freedom during the Italian lockdown. The state lockdown required putting in place safety measures, which limit both public and private activities, imposing social distancing. In several instances, helicopters and drones were deployed to monitor cities and promptly intervene whenever rules were ignored. Aerial surveillance has proven a valid aid in monitoring outdoor activities and affluence of people towards gathering areas such as parks, hospital parking lots, malls, etc.

INAF-OAPA offered its expertise on visible (VIS) and Infrared (IR) remote monitoring by tethered balloons in cooperating with the fight against the COVID-19 pandemic diffusion. A prototype of an aerial monitoring platform was developed as an alternative to helicopters and drones for the surveillance of open-air areas at risk of large gatherings (Chandrasekharan et al. 2016). The platform is made of a highly stable helium filled balloon tethered to ground, equipped with a payload suited for monitoring the presence of people/vehicles remotely and processing the acquired images, to be placed at a fixed altitude by a winch. The selected balloon uses mixed features, based on floating and aerodynamics, to keep a stable stationary altitude for con-

Fig. 1. Skyhook tethered Helikite.

tinuous and synoptic monitoring of vast areas of territory. This system allows continuous monitoring for long periods (months), with a greater level of spatial detail, which can be managed independently by the user according to their needs and with greater variety of data acquired. Other advantages are the improved time to costs ratio and no acoustic emissions. Furthermore, from the bureaucratic side, no licenses are required, just a clearance by the competent authority (NOTAM ENAC/ENAV ATM-05A). Moreover, it is easy to handle because it does not need an expert pilot.

Up until now, this kind of aerial platform was used for advertising or scientific purposes (Ramponi et al. 2018; Peterzen et al. 2005; Masi et al. 2007) in Italy, and in Europe for monitoring and surveillance in the military, oil and maritime sectors or for aerial photography (Verhoeven et al. 2009).

2. Tethered balloon

The balloon is a Helikite made by an English company, ALLSOPP HELIKITES Ltd. in Fordingbridge (Uk). The model of the kite is named Skyhook, whose resumed technical specifications are reported in Table 1 (www.allsopp.co.uk).

The Skyhook is made of a helium filled polyurethane bubble, with a sheet thickness of about 0.9 mm, supported by a rhomboid kite with major diagonal length of about 3.7 m and a minor diagonal of 2.9 m. A picture of the Skyhook is reported in Fig. 1.

The presence of these two parts, the bubble and the kite, allows the balloon to exploit both wind and helium for its total lift. In particular, the selected model has great stability in the presence of strong winds as well as without wind (worst flight conditions in terms of lifting power). The skyhook shows high load capacity (12 kg at 24 km/h of wind speed and 4 kg without wind), and is tethered to ground through a winch, allowing it to be placed at a fixed altitude up to 500 m. Furthermore, it exhibits an excellent volume/lift ratio whereas the mixed aerostatic and aerodynamic technology compensate for the effects of expansion / contraction of gas inside the balloon. The Skyhook is equipped with several tools such as a payload anchoring system, a 12 V winch with dyneema cable (an high strength very light and UV resistant material) with a winding speed of 20 m/min, an inflatable ground station to land and lift-off the balloon, and a safety barometric system to induce forced landing. The safety system is capable of quickly deflating the balloon if the rope were to break or the balloon were to get detached, ensuring its vertical fall within a predetermined safety area.

2.1. On board instrumentation

The payload of the aerial platform is designed to fit the lift specifications of the balloon in the worst-case scenario of no wind (weighting less than 4 kg). The instrumentation is a custom system consisting of two cameras, for VIS and IR acquisitions, accommodated in a vibration damping and pointing system (gimbal), plus electronics for telemetry and remote control (see Fig. 2).

The daylight picture and video acquisitions are performed in remote with a Sony FCB full HD high-resolution camera, with lens able to operate from wide (f=4.3 mm and F1.6) to tele (f=129 mm and F4.7) with a 30x zoom. The CMOS sensor resolution is 1920×1080, with a diagonal length of 1/2.8 inches and pixel side of about 4 µm. The IR acquisitions are entrusted by a Flir Vue Pro 640r thermal

Table 1. Technical specification of the Skyhook aerostat

Helikite Type	Helium capacity (m^3)	Lift in no wind (approx.) Kg	Lift in 25 Km/h wind (approx.) Kg	Max wind speed (approx.) Km/h	Max unloaded altitude (approx.) m
Skyhook	11	4	12	60	1700

Fig. 2. Gimbal that hosts a HD VIS camera and an IR camera for night vision.

imaging camera, which adopts an uncooled microbolometer sensor with dimension of 10.88 mm x 8.704 mm, pixel size of 17 μm and a resolution of 640×512, able to get with its fixed optic, accurate measurements with calibrated temperature for each pixel in a spectral band ranging between 7.5 - 13.5 μm. Both cameras are mounted on an active gimbal that allows them to point towards the area of interest while continuously stabilizing them. To send the stream of the data, the platform is equipped with a 5.8 GHz digital wi-fi transmitter for the real-time monitoring through a ground station (tablet/smartphone/laptop). The gimbal is currently remotely controlled manually, via a joystick radio control. Furthermore, the system is equipped with a GPS for accurately pinpointing a target and to allow for the creation of mosaic maps.

2.2. Trial aerostat launch

The use of this platform, to the extent of the present work, is in the field of aerial surveillance to monitor outdoors activities in areas at risk of assembly, to control the flux of people/vehicles to critical areas and to promptly warn the competent authorities whenever violations of the anti-assembly rules occur. For this purpose, the trial launch of the platform prototype took place in a suitably identified strategic location, which provided enough space for a safe launch and for recovery operations (e.g. sufficiently cleared grounds). The test allowed validating the potential of the monitoring platform from a quote of about 200 m over the sea, to evaluate the mechanical stability of the vector, the optical image and the robustness of the telemetry streaming. To test the HD camera, two images, either without zoom or with 30x zoom were acquired, as reported in Fig. 3.

The preliminary tests performed during daytime hours with the HD camera proved the platform ability to resolve distant objects with an excellent level of detail and stability. According to the estimates, the vision of the HD camera can cover an area of about 1 km^2 around the launch point from an altitude of 200 m, whereas the IR camera could prove useful at detecting heat sources during night-time,

Fig. 3. Images acquired with no (left) and 30x zoom (right).

though with reduced performances due to both a lack of optical zoom and a lower resolution of the detector.

To make the monitoring system complete, a preliminary feasibility study on a software for automated people/vehicles identification from aerial images started in collaboration with the Italian company Injenia. The idea is to provide a proof-of-technology of the available solutions according to use-case needs to identify people within a representative subset of aerial images at fixed altitude to evaluate the software accuracy and efficacy. The proposed solutions would adopt models based on deep learning aimed at object detection and structured on region-proposal architecture and convolutional kernel pre-trained on a reference data-set.

3. Conclusions

To fight the diffusion of COVID-19, INAF-OAPA proposed the use of an aerial platform system, originally designed for environmental checking, to monitor the flux and gathering of both people and vehicles. The system is still a prototype, but offers a promising viewpoint to this purpose. Presently, it is conceived to operate "manned", since it requires the presence of somebody who can monitor the images in real time, alerting the competent authorities whenever necessary. Several improvements are foreseen to be potentially implemented such as remote control, which would allow the on board instrumentation to be handled from afar, and the integration of machine learning algorithms to automatically detect and report potentially dangerous situations, based on number and relative distances between identified people. Such algorithms can be developed in a general framework, separately from the hardware, that is, the tethered balloon, making it a prime tool that can be migrated from Covid-19 surveillance to other fields that require monitoring and remote object identification

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