Horus – a drone project for visual and IR imaging

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Abstract – The focus of the project is to create new approaches to the study of the past through the use of innovative aero-space technologies to measure, analyse and reconstruct the ancient landscape and its remaining natural and anthropic traces.
The équipe, based at the University of Padua, is constituted by archaeologists, egyptologists, mechanical and software engineers, physicists and computer scientists and is now active on the proto-historic site of Rozto in Italy.
The research includes the analysis of the historical records, as old maps and aerial photographs of the past, field use of drones and the creation of a GIS platforms to collect and see the data all together.

I. INTRODUCTION

This project is designed to promote collaboration between aerospace engineering and archaeology to propose new strategies of investigation of the earth from above and reconstruct the ancient world through historical documents and modern technologies.

In this view, Horus project was funded in 2014 by the University of Padua as innovative project proposed by the students and now continues as “Horus 2.0: new frontiers of predictive archaeology, from remote sensing to ground truth”. The name is reminiscent of the Egyptian god Horus, the falcon-headed, who observed and protected the land of Egypt from above, thus drawing the earth and the sky, the two subjects investigated by this research.

Remote sensing represents an increasingly important tool for non-invasive archaeological prospection. In fact, it proves extremely helpful to identify ground anomalies related to sub-surface archaeological structures even in areas where excavation or surveys are not possible due to logistic or economic reasons. Moreover, aerial and satellite data offer the chance to examine ancient man-made structures (sites and buildings) and infrastructures (roads, defensive systems, terraces, canals, agricultural divisions etc.), by investigating at territorial scale.

Among all other methodologies employed, we soon realized that Unmanned Aerial Vehicles (UAVs) were among the most versatile and useful tools for our specific needs, since they provide an efficient way to acquire high resolution data in relatively small time frames. However, our commercial DJI Phantom 2 equipped with a GoPro Hero 3 digital camera did offer enough flexibility and payload to experiment with new settings and sensors. This is the reason why we decided to build a custom UAV specifically designed for archaeological aerial survey.

The instrument was tested in the site of Bostel, where it acquired robust spectral and morphological datasets, allowing us to identify anomalies related to pre-roman structures and thus giving new hints on the spatial organization of the settlement.

II. DESCRIPTION OF ANCIENT CONTEXTS

The archaeological site of Bostel, in the municipality of Rotzo (VI), is located on the western edge of the Asiago Plateau (Italy) at about 850 meters above the sea level in a strategic location for controlling the Assa and the Astico Valleys. The human occupation was sporadic from the middle to late Final Bronze Age and become permanent between the V and II century BC (Second Iron Age). The settlement was discovered in the late eighteenth century and has been systematically investigated by the University of Padua since 1993 [1].
Horus project aims to examine a near-site area within 1.5 km from the center of Bostel. Our goal is to promote a deeper understanding of extent and urban structure of the village, which is not fully accessible for excavation because partly located on private fields. The use of remote sensing will thus help us to integrate current data and target future interventions.

Figure. 1. Bostel archeological site in Rotzo (VI- Italy)

III. BACKGROUND CONTEXT

In recent years the widespread availability of military remote-sensing technologies brought into civilian use, provided a totally new way to look at the past and opened unexplored perspectives for the archaeological research. From the last decades of the XX century to date the technology of Unmanned Aerial Vehicles has increased significantly; at first their use was limited to military purposes, but recently they were also applied for surveillance, forest fire detection, search and rescue operations. The archaeological applications are a natural step forward in the same direction.

Until the last few years, archaeology used to rely on aerial photographs registered for military, cartographic or environmental-monitoring purposes. The possibility to carry out dedicated aerial tests with a relatively low budget is instead leading to a more detailed investigation of the archaeological landscape [2].

IV. THE PROJECT

The project “Horus 2.0: new frontiers of predictive archaeology, from remote sensing to ground truth” is a recently funded interdisciplinary research coordinated by the Department of Cultural Heritage in collaboration with the Center of Studies Activities for Space “Giuseppe Colombo” (CISAS) of the University of Padova. Born from the pilot student research “Horus. Aerial Visions of the Archaeological Space”, the project aims to create a multidisciplinary team devoted to the investigation of archaeological sites using non-invasive, geophysical and aerospace technologies. Three test areas were chosen to evaluate a set of different technologies and analytical protocols: the protohistoric village of Bostel, in the municipality of Rotzo (Vicenza, Italy), and the graeco-roman village of Tebtynis (Fayum oasis, Egypt) with its near-site and the Venetian lagoon in northern Italy. The archaeological, historical and environmental differences of the three contexts offered a wide range of challenges, allowing us to examine and implement various methodological solutions.

Several tasks are under investigations:

• the use of a commercial quadricopter for aerial imaging of the local pre-roman site of Rotzo and the development of a custom drone, specifically designed for the archaeological research, for aerial imaging (in different parts of the light spectrum) of the same site with the idea of extending it to other sites;

• the selection of a visual camera for aerial imaging (from camera calibration to data acquisition);

• the development of the pipeline for image processing;

• self-acquired and historical ortho-photo sequences will be mosaicked to create Digital Elevation Models of Rotzo. All the acquired imagery (that will also include radar data and IR images) will be post-processed, enhanced and interpreted according to archaeological and scientific methods.

• the creation of a GIS to better contextualise the topography of the two so different sites and their artefacts and to reflect on the data collected with those various instruments.

V. TECHNOLOGIES

In the past decades images taken from aircrafts have been utilized in archaeological research to provide a perspective that enhances ground features; with the use of instruments sensible at different wavelengths also hidden features can be revealed and differences in ground level, soil density and water retention can be highlighted, revealing the presence of buried features.

Horus project aims at using low cost UAV technologies for on-site investigations: a custom designed octocopter drone will be equipped with both visible and IR cameras. The custom drone will provide an increased payload capacity and improved flight duration in comparison with the available off the shelf commercial ones.

The final configuration has been selected after an extensive tradeoff study taking into account ease of operations (take-off, flight and landing), low susceptibility to wind and turbulence during flight and repeatability in image capture quality.

The main structure is a foldable commercial assembly, on which a custom designed gimbal for hosting remote observation sensors is connected. Overall mass of the drone including all subsystems is around 8 kg with a maximum allowable payload mass of 4 kg. Flight operations are achieved by controlling eight rotor wings with 15” blades through a 3DR Pixhawk autopilot system and trajectory and attitude can be manually controlled or GPS guided (through dedicated proprietary software) and tracked to allow geo-referenced data acquisition.

Figure. 2. The Octocopter final pre-flight check

Figure. 3. The pixhawk autopilot system (left) and the Rasberry acquisition board (right).

The octocopter is currently equipped with a GoPro Hero4 camera and a Flir Lepton thermal camera, but the gimbal structure has been designed to host also and a LiDAR Lite V2/Sparkfun unit to build up a complete suite for remote sensing.

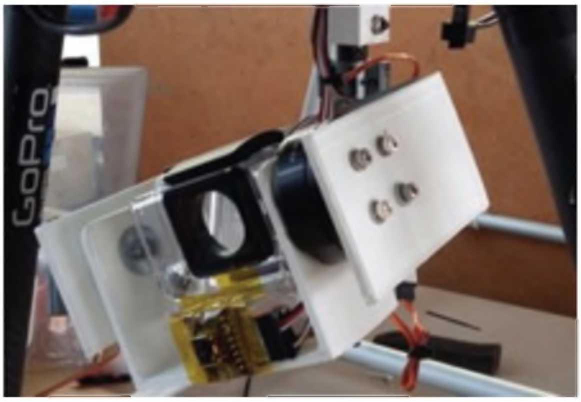

Figure. 5. The designed gimbal; the 3 DOF are controlled via a dedicated board.

Correct pointing of the VIS and IR cameras is controlled with a closed loop by a dedicated software implemented on an Arduino architecture using inertial sensors for attitude determination. Images are acquired by a dedicated on-board Raspberry PI2 computer, tagged with drone timing and position data and then stored onboard for later analysis. Some information on image processing (number of images and relative tagging) are also sent along with drone flight information and health check to a ground receiver through a dedicated telemetry channel. Power is provided by two lipo battery packs (up to 15000 mAh), able to guarantee an overall flight time between 25 to 40 minutes (depending on weather conditions).

The octocopter has been tested thoroughly in several flight campaigns focusing on the optimization of stability in different operative configurations. Due to the intrinsic criticalities of such type of flight machines (high center of gravity, low moment of inertia and high wind sensitivity) and the complexity of coupled trajectory/attitude dynamics, a dedicated approach is needed to address control, stabilization and disturbance rejection.
The PID controller for pitch/roll and yaw has been tuned for hovering and flight so that the closed-loop system meets the objectives of: stability robustness, fast transient response and settling time, steady-state accuracy.

VI. FIRST RESULTS

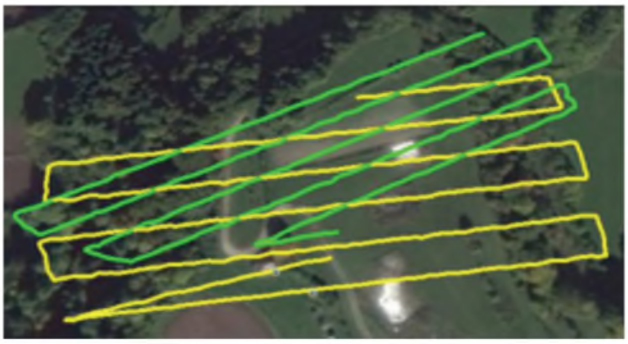

Figure. 4. Trajectories track of the flights.

The flight was performed on the 6th of June 2016 during the morning in order to exploit the good weather.
Flight altitude was approximately 25 m, allowing resolution of 1.5cm/pxl and 30cm/pxl for the GoPro Hero4 and the Lepton cameras respectively.
The total flight time was around 40 minutes (with two sets of batteries).

All the existing sites were mapped and a 3D reconstruction was achieved (see Figure. 6 as an example). Unfortunately, not all the IR images can be correlated with the corresponding visible image due to a lack in the communication software between the two cameras. Some of the acquired images are shown in Figure. 7 and Figure. 8. Data are still under investigation and updates are expected; especially in those areas not observed yet by ground analysis.

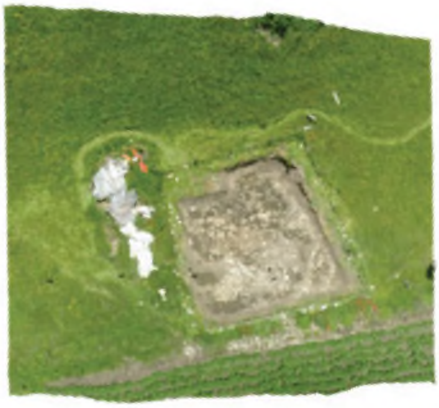

Figure. 6. 3D reconstruction of site denoted as site D.

Figure. 7. Left, visible image of site B; right, IR image of the same site.

Figure. 8. Reconstruction of ancient house: left (visible) and right (IR) images.

VII CONCLUSIONS

A project to promote interdisciplinary and collaboration between aerospace engineering and archaeology developing new strategies of investigation of the earth from above and reconstruct the ancient world through historical documents and modern technologies has been funded by the University of Padova Students' project in 2014. A drone for imaging in visible and infrared spectrum has been developed and first *archaeological* flight has been presented. Now with "Horus 2.0" new activities for improving the main hardware and the sensors is ongoing and updates are expected in the next months.

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