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SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 7, Issue 1 (2017), 29-38
e-ISSN 2239-4303, DOI 10.2423/i22394303v7n1p29

THE USE OF UAV TECHNOLOGY IN TOPOGRAPHICAL RESEARCH: SOME CASE STUDIES FROM CENTRAL AND SOUTHERN ITALY

Giuseppe Ceraudo, Paola Guacci*, Alfio Merico**

*University of Salento – Lecce, Italy.

Abstract

The paper highlights the large potential of the UAV (Unmanned Aerial Vehicle) remote-sensing technology applied to the Ancient Topography sector. There are several areas of application in which this new technology represents a useful tool, from the survey and monitoring of ancient monuments to the expeditious analysis of entire territorial sectors. Therefore occur some case studies conducted by the LabTAF of the University of Salento which have, as intervention centers, the Roman City of Aquinum (Southern Lazio), the Vicus Ad Pirum along Via Traiana and the territory between Lecce (Lupiae) and San Cataldo.

Keywords

UAV, aerial archaeology, landscape archaeology.

1. *Introduction*

Recently, the topographical studies have made use of new remote sensing instruments, the Unmanned Aerial Vehicle (UAV). The improving of the methodological approach, which comes out of the adoption of these instruments, has been widely appreciated in the context of several projects carried out by the Laboratory of Ancient Topography and Photogrammetry (LabTAF) in some ancient centers of Central and Southern Italy. The use of UAVs for topographic surveys represents today the latest innovation from the methodological point of view and it approaches the indispensable use of the traditional aerial photogrammetry.

In recent years, the great success of experiencing drones in archeology is due, in particular, to the fact that it is possible to produce, in a totally independent way and in a very short time, a quite few number of aerial imageries (vertical and oblique), that is indispensable for the archaeological work, in general, and for aerial topography work, in particular. Not only speed of acquisition and autonomy, but also the cost-effectiveness of the operations and the repeatability of the overflights during the same working day represent fundamental aspects that have led to the widespread use of such equipment.

The type of UAVs used by LabTAF during remote sensing activities are two: fixed-wing drone and multicopter drone, equipped with a 24 megapixel camera, which currently results the one with highest resolution, between all the compact cameras. The combined use of the two models has proved to be necessary to achieve the research objectives in our projects. Specifically, the fixed wing drone, allowing to cover in a few minutes large areas of land at altitudes usually between the range of 70-150 m above sea level, has been revealed extremely essential for aerial reconnaissance projects at low altitude on the detection of archaeological traces or to the systematic monitoring of archaeological sites of special interest; the multirotor (hexacopter) is mainly used to document archaeological sites at even lower altitudes (which usually do not exceed 30 m in altitude), under excavation, even with prospective filming, making also use of a reclinable *gimball*.

With reference to the operating activities and to the gained experience, the recent use of UAVs as a new tool for aerial reconnaissance allowed to make some general point examined on a case-by-case basis. Firstly, it has always been useful to perform preliminary surveys to evaluate the environmental conditions of the area to be flown over, especially in the case of urbanized areas or areas close to population centers. However, it is

also recommended to make preventive inspections in case of flying over rural settings to realize the useful maneuvering space, especially in case of operating with a wing-fixing drone. In these cases, it has been convenient to evaluate the presence of fixed obstacles (trees, electricity lines, etc...) that could constitute a clear danger especially during take-off and landing phases in which the aircraft's altitude may necessarily vary. On a precautionary basis, it has been useful consider all the characteristics of the area and thus, not only the presence of any obstacles but also the type of soil (sandy, stony, flat, slightly wavy) to avoid landing on disconnected surfaces and damages to the vehicle.

Among the types of possible flight to the supplied aircraft (scheduled, aided and interactive controlled flight), the gained experiences have led to operate only with the "scheduled and aided" flight and then to plan the flying mission directly from a computer, which in this case constitutes a *Ground control station* (Fig. 1-2).

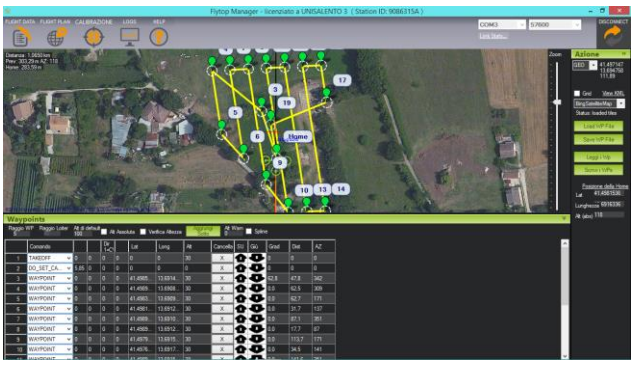

Fig. 1: Plan of flying mission and flight parameters (waypoints, number of strips, altitude)

Fig. 2: Flight paths on ancient *Aquinum* (in red)

The pre-set flight, in which certain values are established, including the parameters of altitude, the number of waypoints and the extent of the area to be covered, allows to acquire various frames which, edited with appropriate *photomerging* software, become particularly useful for photogrammetric uses. Similarly, it has relied to pre-set flight missions for the resumption of the excavation areas and thus for purposes related to the archaeological survey.

Sometimes, the "scheduled and aided flight" has been performed in auto mode. This means that the flight mode is fully automatic, without computer programming with controls managed remotely by the operator. The "automatic" flight then, has been considered useful whenever you had to have complete autonomy of the movements of the means and, for example, to make perspective images and video, in this case using necessarily a *gimball* managed through the *data link*.

This happened in the case of the monitoring of ancient monuments of which it has been created reclinable detailed images: it is the case of the flight carried on the ancient structures of the Roman theater of *Aquinum* where the primary requirement has been to maneuver the drone inside the ancient remains making extemporaneous marks. In this case the use of a video monitor, grafted on the remote control, allowed the operator to drive the aircraft according to a route designed at the moment.
About the equipment used, nowadays, it has only experienced the use of compact cameras at high resolution, postponing at a later time the use of thermographic cameras, and in particular the equipped camera is the SONY ALFA 6000 model. Among the various settings, the one which has been detected the most suitable is in Tab. 1:

Tab. 1: Sony Alpha 6000 settings detected

Image Size	24mpx
Aspect ratio	3:2
Image format	JPEG
Exposure	± 0.0
ISO	ISO 400 (MANUAL). This value is to be increased in the darkest environment and decreased in sunnier environments.
Image point	Active
Shooting mode	Multi shot mode (preferable to the single frame mode)
Aperture	Choose a value between 5 - 6-11 (in normal cases set the value 8.0)
Shutter speed	Choose a value from 1/500 up in case of sunlit environment (eg. 1/15)

2. Aquinum (Castrocielo, Southern Lazio)

As part of the Ager Aquinas project, since 2004, the LabTAF has been pledged in archaeological investigations about systematic reconnaissance of the territory starting from 2009 and in annual excavation campaigns, thanks to which they are bringing to light some important public buildings in the central area of the city: the baths, the Theatre and the "Edificio Absidato" (or Tempio di Diana; Ceraudo 1999, 2001, 2004, 2008a, 2012; Ceraudo, Murro, Petrucci, Ugolini & Vitale, 2014). Already during this research, the study of historical aerial photographs of recent production, the latter derived from aerial reconnaissance at low altitudes, have helped to identify the exact size of the city (approximately 100 hectares) and its urban fabric, regular but non-orthogonal. The use of UAVs in Aquinum is aimed at the general mapping of the entire urban area, for the detection of any new archaeological traces in addition to those already known to better define the internal organization of the blocks of buildings.

Among the most significant traces identified with the new archaeological campaigns it should be pointed out those found in some fields laid out in the Eastern part of the city, at East of the excavation of the baths and immediately at North of the Via Latina (Fig. 3).

In particular, cropmarks have been recognized, two of which better distinguishable in relation to the other (average size of about 6x7 m), presumably to identify with small buildings but still from uncertain function (Fig. 3 A).

In the same field, close to the traces described above it is possible to identify others, showing less defined outlines that, in the same way, might indicate the presence of additional buried

Fig. 3: Some cropmarks in the urban area of *Aquinum*: small and medium-size buildings (A-C) near two buried streets (B-D).

structures. These buildings are oriented immediately at South, compared to the main roads represented by the Via Latina, and to the stretch of road seen in part as cropmarks and in part as soil marks of about 200 m (Fig. 3 B).

The road axis, half recognized as soil marks, is to be identified with the decumanus placed about 70 m at North of the Via Latina. And a little further at East, immediately at North of the Via Latina there are other recognizable traces of buried structures with a roughly North-South orientation. Although they are better distinguishable from those already reported, these tracks from rectangles (12.5 to 8.5 x 7.5 to 6 m), may be associated on purely hypothetical smaller buildings, whose destination of use remains uncertain although the orientation compared to the main decumanus could be state their consistency with the general plan of the city (Fig. 3 C). Similar traces were detected in the adjacent field beyond the Via Latina in previous flights made by airplane (Fig. 4).

In the eastern section of the same field, the analysis of frames has identified a stretch of road

Fig. 4: Cropmarks of buried buildings (flight 2005)

with an orthogonal orientation to the Via Latina of about 35 m. This road is part of the road axis with a North-South orientation, recognized only in the same settlement sector (Fig. 3 D). This and other frames taken during the last flight missions allow a better understanding of the *Aquinum* urban fabric, helping the upgrade of the archaeological map of the Roman city (Fig. 5).

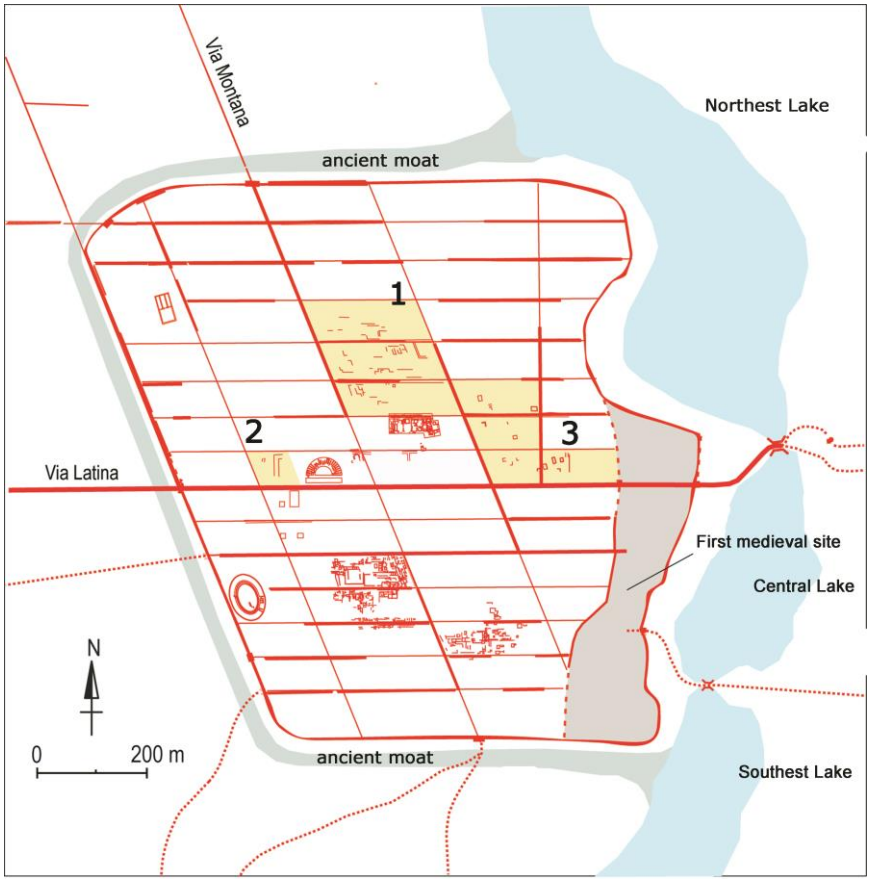

Fig. 5: Schematic plan of *Aquinum*: numbers show the area with new cropmarks.

In the case of *Aquinum*, UAVs have also been used for the study and the thermal building documentation, which is at the center of the city at North of the Via Latina.

The frames taken at various altitudes on the ancient building allow the creation of 3D models

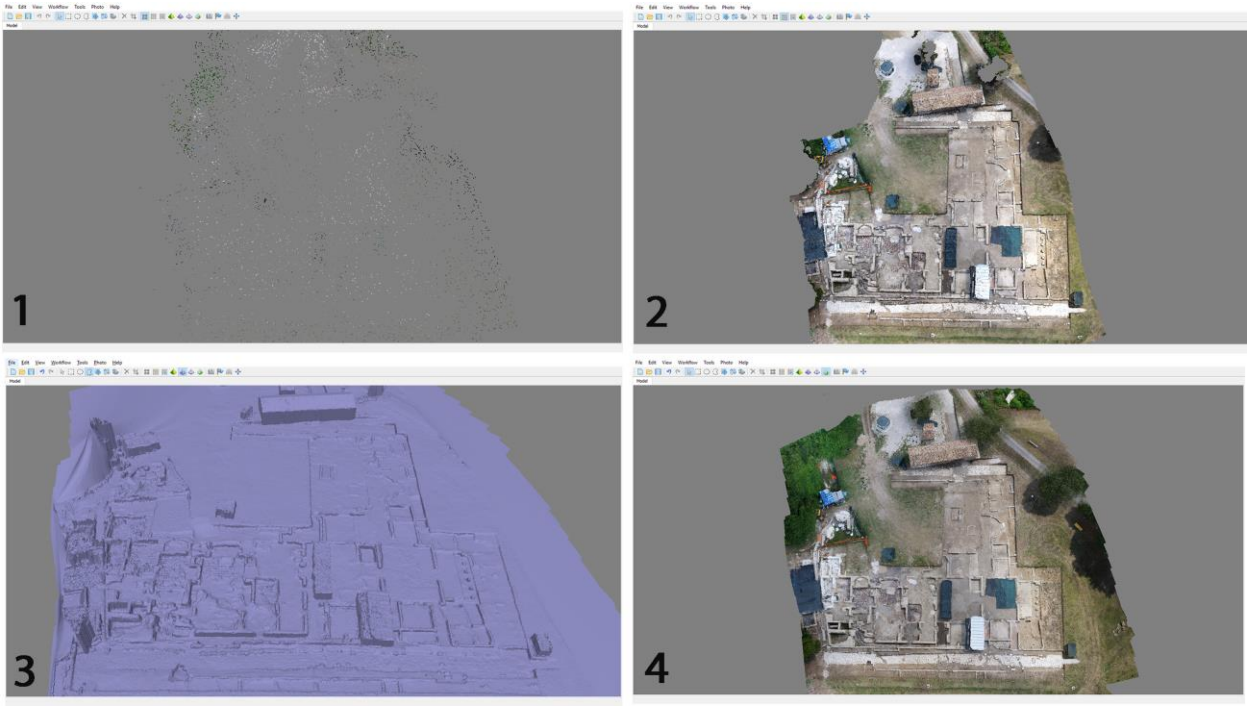

Fig. 6: Post-processingof UAV imageries for the baths of *Aquinum*: sparse cloud model (1); dense cloud model (2); mesh model (3); texture (4).

Fig. 7: Orthophoto of tha baths of *Aquinum*.

Fig. 8: Cropmarks show buried ancient buildings of the *vicus Ad Pirum* (Ceraudo 2008b).

and georeferenced orthophotos, the latter essential to accelerate the characterization of the wall structures (figs. 6-7).

3. Ad Pirum (Troia, nothern Puglia)

The aerial topographic surveys conducted within the Via Traiana project are aimed at the analytical reconstruction of the route of the ancient main road, built by Trajan in 109 A.D. from Benevento to Brindisi (Ceraudo, 2008b). The researches carried out on the area have been accompanied by a meticulous work of interpretation of the many visible traces of historical and recent aerial photos. In this way it has been possible to identify a large number of rural settlements, often identified with villae rusticae (Ceraudo & Ferrari, 2010), and various boards related to the agrarian division of the Roman age. More recently, at the aerial photos taken in the traditional way, it has been added those arising from the use of drones especially in Perrazone, where the vicus Ad Pirum was located and that served as statio along the Via Traiana.

The relevant structures of the ancient vicus had already been identified as vegetation traces of aerial images to which corresponded a wide area of about 25 hectares of clay fragments (Ceraudo, 2008b) (Fig. 8).

More recently, archaeological emergency investigations allowed to highlight part of the housing/productive sectors, relevant to the ancient funerary late stage of the small town, in an area that had never returned any particular archaeological trace. In this specific case the use of drones has been dictated by the need to carry out aerial expeditious reconnaissance, with reference to the fields of excavation, to conduct a comprehensive graphical documentation (Guacci, Merico, Minaya, Tulumello, Ceraudo & Muntoni, 2017) (Fig. 9).

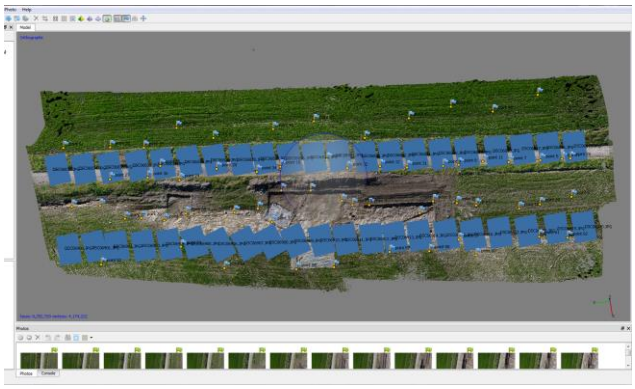

Fig. 9: Drone's images positioning at *Ad Pirum* excavations

4. The area between Lecce and San Cataldo (Lecce, Southern Puglia)

The Portus Lupiae project aims the analysis of the remains of the Roman pier in San Cataldo and the systematic investigation of the area between Lecce (the ancient Lupiae) and the Adriatic coast, in the drawing up of the archaeological map and definition of the dynamics of settlement occurred in the course of the centuries (Valchera & Zampolini Faustini, 1997; Merico & Sammarco, 2014). During the project it has made an extensive use of historical and most recent aerial photographs, the latter derived from aerial reconnaissance at low altitude (Ceraudo, 2013) and from the use of UAV technology.

One of the major achievements has been the reconstruction of the majority of the road, which linked the old city with its port. The course of the ancient roadway survives and it is, in part, some places still practicable nowadays, in part of carriage roads on the outcrop, or as visible marks only on aerial photos taken in the mid-twentieth century (Fig. 10).

Fig. 10: Cropmarks of carriage roads on historical aerial photos

The largest number of carriage roads has been recorded close to Masseria Ramanno (Fig. 11), where in Roman age it was located a settlement with production of amphorae facility identified through direct and geophysical surveys (Fig. 12).

Fig. 11: Carriage roads near Masseria Ramanno

Drones have been used, in addition, to document the remains of the Roman pier in San Cataldo (Fig. 13). The excavations and survey, launched in 2004 and now concluded, made it possible to reconstruct the appearance of the ancient structure, the half-moon shape made of opus coementicium with two vestments of square blocks (Fig. 14; Sammarco & Marchi, 2008).

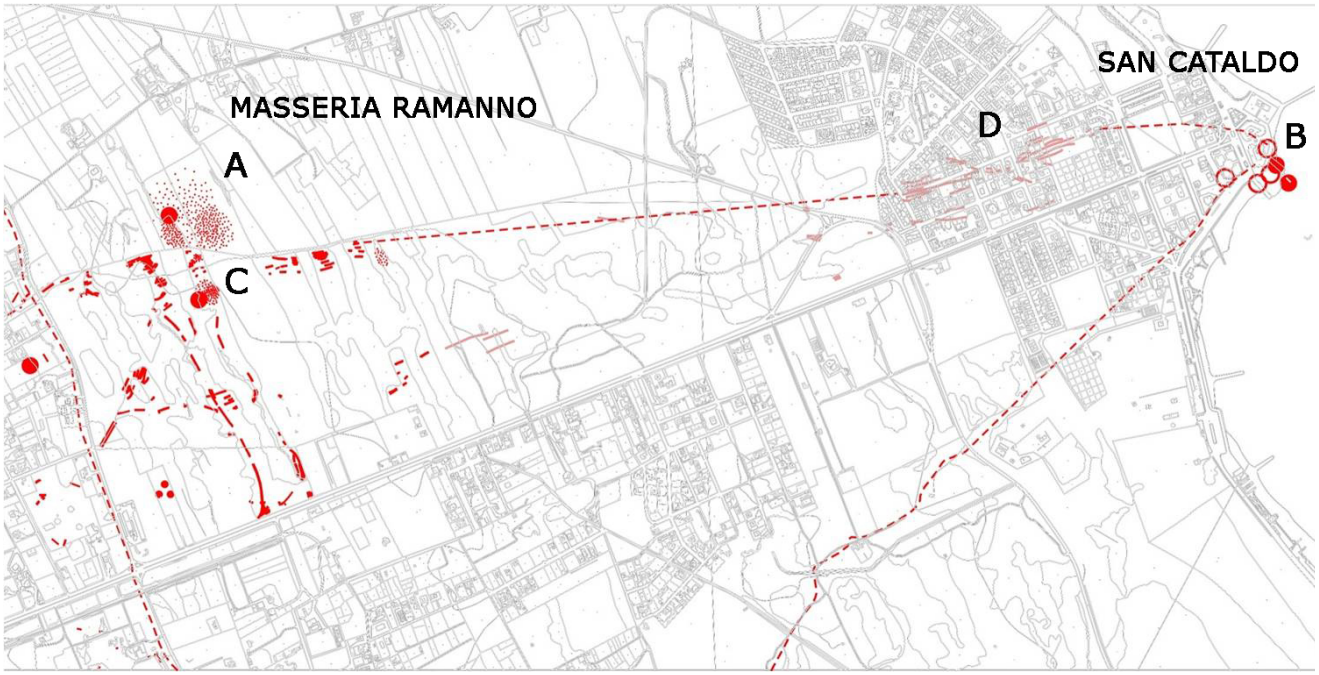

Fig. 12: Lecce - San Cataldo survey: localization of rural settlement of Masseria Ramanno (A) and of the Roman port (B). The ancient road survives near Masseria Ramanno (C) but it is also visible as cropmarks in historical imageries (D).

Fig. 13: San Cataldo. The excavated Roman port on aerial imagery from multicopter drone

Fig. 14: Virtual reconstruction of the Roman port (by Ivan Ferrari)

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