[Proceeding] 3D MODELLING FROM UAV DATA IN HIERAPOLIS OF PHRIGIA (TK)

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3D MODELLING FROM UAV DATA IN HIERAPOLIS OF PHRIGIA (TK)

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Abstract:

In areas of archaeological excavation with architectural complexes, the generation of 3D data and their spatial information updating can now benefit from UAV photogrammetry. This technique shows a very rapid development in many fields, as it provides effective results for high-resolution and detailed surfaces, adding to both quickness and suistainable costs, quite irrespective of the form and extension. That is very important in Documentation phases of Cultural Heritage. In the field of archaeological researches, the nadir view from low altitude has always been a preferential point of view, then the generation of very large-scale models and orthophotos is of great interest today, and it seems to promise high future developments. So the paper focuses on a workflow to obtain photogrammetrical products generation using eBee system, by Sensefly, of growing popularity in the scenario of survey techniques. The potential of outcomes is also given by the selected monumental case studies in the city of Hierapolis in Phrygian, on which the MAIER (Italian archaeological Mission of Hierapolis) operates from the 60s of the twentieth century. The variety and complexity of the buildings, as well as the height of their ruins offers numerous trouble spots that is interesting to deal. A particular attention on the accuracy of DSM (Digital Surface Model) will be evaluated and reported thanks to the GCPs (ground control points) that have been easily measured since these aerial photogrammetry experiences by UAV are the last of extensive previous metric surveys conducted in the recent past.

Key words: UAV, DSM, aerial photogrammetry, Archaeological Heritage, 3D modelling, maps updating, data integration

1. 3D Documentation by UAV in archaeological sites

In Archaeological context, daily prone to environmental and human risks, the whole Heritage monitoring process, must be steadily fed by dedicated investiments and kept under control by careful documentation, designed as a perpetual practice during years. From this point of view the the digital 3D perception and handling, and in particular the use of geomatics integrated techniques, allows to conceive a 3D survey as a complete and detailed database of information, that may be instantly queried to obtain multiple representations and multidisciplinary analysis can be conducted on it. Moreover, 3D information derived from aerial and terrestrial sensors, belonging to the same spatial system, can be integrated to generate multi-scale and multi-resolution detailed models, according to time and space (Aicardi *et al.* 2015; Moussa *et al.* 2012). This is a part of continuous documentation processes and nowadays it become more and more crucial to reach the characteristics of completeness needed by multidisciplinary context, as archaeological ones. In particular, the production of surface models from aerial sensors is useful for terrain analysis and reconstructions, structural analysis, studies of materials and decay.

For the data acquisition phase, in these last years many platforms have been developed to produce, update and integrate various geospatial information, according to different mechanics features, devices equipement and organization of flights (Colomina and Molina 2014; Themistocleous *et al.* 2015). Several technological refinement in RPAS (remotely piloted aerial system) are taking on by research, both from the point of view of the hardware component (image acquisition) both in the software (data processing). From an operational point of view, platforms mostly employed in manifold types of applications are generally the fixed wings and the multicopter drones. One of the lately updated and cost-effective one is the eBee SenseFly autonomous drone (Fig. 1), used in Hierapolis site. It is a fully automatic UAV with a central body equipped by sensors. The main characteristics are a maximum flight time 50mins, flight speed 11-25 m/sec, radio link range 3km. SenseFly manages the eBee platform with all the information about the flight plan through eMotion software based on a photogrammetric approach.

2. New aerial documentation in Hierapolis: 3 flights for 3 goals

Here it will be presented the acquisition of UAV data and the production of surface models (DSM) from aerial

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sensors for terrain analysis and high-scale representations of the current state of three excavation areas in Hierapolis (Pammukkale, TK) with the aim to update spatial information. Hierapolis is an ancient city of Phrygia, founded on a calcareous shelf, rich in springs emerging from subterranean galleries. (D'Andria 2015) The geological context of the site conditioned the ancient and current arrangement of the city, the Pamukkale village, characterized by frequent destructive earthquakes, because of the location in the northeastern and seismically active side of the Denizli Basin, which is a 70 km long graben. (Alcicek 2007) During the last years, the MAIER (Italian archaeological Mission of Hierapolis) activities have identified two very important monumental buildings. Starting from 2008, many huge restoration activities have been achieved by Turkish or foreign funding. Restoration works concerned the Severian Theatre façade, the S. Philip church, the the Martyrion and the excavation of the main road of north Necropolis. In 2011 the church built upon the tomb attributed to the apostle Philip has been brought to light. The year later the famous Ploutonion cave, considered the "entrance to hell", has been discovered. Three very important areas of the ancient city have been selectet for this documentation project in Hierapolis: the central area pertaining the Plutonium next to the Apollo sanctuary area; the massive masonry building of the so-called Terme-Chiesa and the Northern Necropolis area. It is interesting how the surveys have been conducted very similarly from a technical point of view and they obtained objectives declined to individual needs of the study areas (Fig. 2).

Figure 1: The setting up of the fixed wing eBee platform with the customized camera and take-off phase.

For the data acquisition, the eBee drone was equipped with the Canon S110 RGB (12 MP, CCD size 7.44 x 5.58 mm). According to the Turkey UAV regulations, platforms under 4kg of weight and under 100m of altitude could flight without any authorization. Furthermore, pursuance of the aims of the project the GSD (Ground Sampling Distance) was set up at 2 cm in order to achieving suitable information for very accurate large maps. The photogrammetric process, by Pix4D software is composed into different steps: initial processing of interior and exterior camera orientation and point cloud densification. The final step of the workflow is the production of DSM and a complete True Orthomosaic. True orthophotos are common end-products obtained from digital surface models where the aerial images are rectified from a perspective to an orthographic projection using an underlying DSM, the single orthos are automatically clustered in the software. The Plutonium area (0.11 km2), for example, was covered in about 10 minutes (80% overlapping in both directions) at an altitude of 57.2 m, with measurement of 20 GCPs. The Necropolis area is wider, the flight altitude is almost 100m, 0.23 km2 with 18 GCPs, and 22 GCPs in the Thermal Bath Church (0.12 km2). It is very interesting the result of accuracy of the models, which is around 1 centimeter for GCPs and around 2 cm for the CPs. This data concerning the promising precision, along with the resolution that is around 2 cm per pixel for flights of lower altitude and 3cm per pixel for the flight to the higher altitude of the Necropolis, it means that the scale of the outcomes is between 1:100 and 1:200. The main purposes of the photogrammetric flights on the areas were the revising of available documentation. In particular, for the Plouonium area, the integration with the updating data after the last excavation near Apollo's sanctuary; for the Terme-Chiesa the integration of the previous terrestrial LiDAR survey with aerial models; for the Necropolis the aerial documentation and production of an updated terrain model for pathways elevation analysis.

Figure 2: Othophoto of the Plutonium area and Apollo Templum.

Surely, drone surveys and the resulting products such as orthophotos and DSM cannot be compared to the extreme detailed models offered by terrestrial LiDAR (Fig. 3), particularly for the vertical portions of the structure. It's important, however, to consider that all the elevated parts of the structure, including the top surface of the large bumpy cylindrical vaults, are difficult to measure from the ground, and this experience of integrating the terrestrial and aerial survey by drone, not reached before on Hierapolis data, in other occasion was effectively accomplished. For the North Necropolis area interested by the 2015 drone flights, the main aim was the documentation of terrain comformation, in relation to the pathways accross the funerary area that extend at the edge of the west travertine terrace. The mounds which are particularly common represent the oldest burial (II - I cent. BC). At a later stage, from the end of the first century A.D., some burial structure had been placed, arranged along the main street and along internal lines. The detailed campaign of necropolis map updating, that has positioned the large number of sarcophagi (Scardozzi and Ahrens 2015) is essential to understand the organization and the temporal succession of graves; the drone survey provides a very

substantial completion to that with a highly detailed terrain model on the tissue of the necropolis and its domestic routes. Up until now, these data were not available and we believe that the ability to measure on a digital model every possible level or height differences within the necropolis points is an important opportunity in the perspective to continue the studies on this area. (Fig. 4)

Figure 3: The entire complex and corresponding views of LiDAR model and the drone one, quite deficient in upstanding walls, especially high.

3. Perspectives

These type of aerial acquisition and processing, starting from the same device equipment, have been analysed and compared firstly according to the context area on which they have been planned, then on the type of terrain and buildings features, finally related by the outcomes and their numerical evaluation. The results of the presented three photogrammetric projects open the way to assess the drone survey as extremely effective in archaeological contexts, thanks to the versatility respect to the archaeological features of the sites and structures and the excavation process needs. In perspective, it can be expected that the acquisition phase, the elaboration process, and the results will be more and more strictly linked to information required for the documentation purposes. 2cm resolution and less than 2cm of metric accuracy show that these products are key elements in the documentation updating in aechaeological contexts. Another important perspective is the ability to equip flight systems with other sensors that may give significant support to the archaeological investigations, especially with predictive tools, together with the need to put in safety conditions the excavations area.

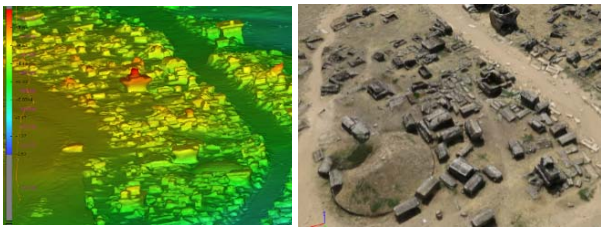

Figure 4: A view of of Necropolis: DSM in range color and texture.

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