Digital survey from drone in archaeology: potentiality, limits, territorial archaeological context and variables

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Abstract. The ease of piloting drones, the increasingly high performance of sensors, range of action and autonomy of the platform in flight, combined with an apparent simplicity of realization of 3D models through modern photogrammetry (based on algorithms of Structure from Motion and techniques of Computer Vision), have created a real boom for use in archeology. The trust placed in these new technologies has not always allowed a careful analysis of the limits of these tools and methodologies. In fact, these technologies are often used badly or not to their full potential, probably due to the absence of a general manual and because they are technologies in constant development. The aim of this paper is the discuss of potentials and limits of the use of drones in the documentation of archaeological sites, which are high dependent by the territorial archaeological context and several variables that will be argued.

1. Introduction

The UAS (Unmanned Aerial System) or RPAS (Remotely Piloted Aircraft System), in the common jargon called by the generic name of "drone", have definitively entered in the field of cultural, monumental and archaeological heritage. Over the years, there have been national and international experiences that have seen approaches to different platforms such as the "Mini-Helicopters" [1] and "Fixed Wing" drones [2]. In the archaeological field, aerial photographs, taken more and more frequently through drones, make it possible to detect the presence, size and shape of archaeological sites that are often invisible at ground level, and the contribution these new instruments have made is great. In recent years, in the field of photogrammetry and Remote Sensing in archaeology [3], drones are becoming increasingly performing and economic tools.

The aerial photography is being supported by photographic acquisition from UAVs and through the use of SfM (Structure from Motion) techniques, 3D reconstruction of entire territories [4] or three-dimensional survey of archaeological excavations [5]. Despite the few years that separate us from the first pioneering studies [6], the technological evolution and the quality level of drone applications have greatly improved.

The relative ease of piloting drones, the increasingly high performance in terms of sensor quality, range of action and autonomy of the platform in flight, combined with an apparent ease of realization of 3D models through photogrammetry, have created a veritable boom in use in the archaeological field. The extreme trust placed in these new technologies, used both with excellent results and
sometimes not to the best of their potential, has not always allowed a careful analysis of the limits of these instruments and relevant methodologies [7].

In fact, many authors highlight neglect of the level of accuracy of the survey or an incorrect or partial interpretation of the data. This happens because often there is a lack of technical and theoretical know-how underlying the data acquisition, processing, management and understanding process. At the same time, the absence of a manual for the correct use in the archaeological field of UAV platforms is complained. Therefore, on the one hand we have ever more efficient tools, on the other hand we often find an inadequate methodological approach that can strongly affect the interpretation of data or the quality of information (which may also involve damage even to the preservation where the surveys are carried out for the restoration project or of securing a cultural asset).

This article will discuss the potential and limitations of the drone survey for the documentation of archaeological areas and sites in a state of ruin. Furthermore, the importance of the archaeological territorial context will be argued and some specific variables to be taken into consideration during the entire workflow will be illustrated.

2. Drone survey
To achieve a complete photogrammetric coverage of a territory it is necessary to carefully plan a series of operations. The first involves the identification of the study area: the extension of the site is determined, with the relative boundaries, and the critical situations to be investigated are analysed such as the presence or absence of any natural obstacles or anthropic structures (especially if the drone will flights very low), the morphology of the land and presence of known or unknown points of archaeological interest. To do this is useful to utilize software GIS as Qgis or Google Maps, which consent us to know the area of the operation. For example, Google Earth it was very helpful for the planning (Fig. 1) of the digital survey of the Reggia of Caserta (Caserta, Italy).

![Figure 1. Identification of the survey area. Reggia di Caserta, Caserta (Italy)](image)

The second phase involves the technical preparation of the drone (battery assembly, connection to the GPS signal, etc.), take-off, flight and landing. The photogrammetric acquisition from a drone involves zenithal and oblique photographic acquisitions, at a constant and variable height based on the
performance of the camera, the degree of detail to be obtained and the desired perspective. Instead, to be able to create a 3D model from a drone it is necessary to acquire images in order to cover the entire surface of the object to be detected, guaranteeing a sufficient degree of overlap between the different images [8]. Once the photogrammetric acquisition beat is carried out with the UAV, it is necessary proceed with the detection on the field of the geographic coordinates of some fixed points through GPS or Total Station, a fundamental process for the subsequent geo-referencing of the 3D model.

The photos taken are often correct, as they are often taken by action-cam with a strong fish-eye, the images are not useful (that is with too much overlap between them, blurred, taken on take-off or landing) are removed. They are then loaded and processed into dedicated software based on SFM algorithms, which can directly exploit the resources of their PC (Agisoft Photoscan) [9] or external server (123d catch) [10]. These software allow, through a semi-automatic procedure, to obtain the point cloud, the mesh, and the final geo-referenced texturized model.

The 3D models and the related derivatives such as Google KMZ, orthophotos and DEM (Digital Elevation Model), inserted in GIS systems, allow an in-depth analysis of the territory under study, allowing a qualitative and quantitative increase in the archaeological data, which ranges from analysis of the micro-relief to the production of dedicated map, from the calculation of the fastest or least routes to the drawing up of plans.

3. Potentiality, limits, territorial archaeological context and variables

In dealing with a study an area with archaeological potential, or a site that is already known and partly investigated, using UAV platforms, it is necessary to consider several variables, which will be explored in detail below. The drone used (and therefore the quality and typology of the sensor mounted on it), the acquisition context (light condition, land morphology), the computing capacity of the computers for processing the acquired data, the level of preparation of the archaeologist, architect or restorer of data management and interpretation, for example, play a key role from the first acquisition phase to the last interpretation.

Summarizing, we can identify six variables (Fig. 2):
- quality of the equipment;
- type of the equipment;
- survey method;
- data processing method;
- data acquisition period;
- correct data management;
- experience and interpretation skills.

![Figure 2. Territorial archaeological context and variables](image)

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These variables are closely linked to the territorial archaeological context, understood as an area in which an archaeological site (village, necropolis, for example) or the remains of the ancient human exploitation of the territory (water channelling works, agricultural divisions, etc.). Each landscape has its own identity and is characterized by a historical evolution defined by anthropic factors (urbanization, agriculture, etc.) and natural factors (landslides, fires, floods, etc.) interconnected. In dealing with the study of a specific archaeological territorial context, it is essential to consider the dynamics of abandonment, spoiling and refunctionalization of the area, and the time that separates us from it.

Therefore, some archaeological sites are better preserved than others in the elevations of structures or their mark in the ground is still very perceptible (ditches, terraces, for example). These are generally those settlements abandoned no more than a thousand years ago, with no continuity of life and located in areas not exploited for agricultural purposes. "Reading" these sites from aerial photos or from 3D drone models appears less complex and more impactful than those that are preserved only in the foundation bases. In support of what has just been said, I bring two case studies that I have dealt with in the past (Fig. 3). As can be seen, the analysis from drone of the big and articulate roman villa of San Giovanni of Ruoti is very hard to do due to the millennial spoliation and the modern use of the land for agricultural purposes (Fig. 3a) (around the excavation area there are also other structures investigated in the past but invisible from above); instead, the topographic analysis in the case of the castle of Lauria (Lauria, Pz) is not much hard for the better state of preservation of the site (Fig. 3b).

Figure 3. A) Roman villa of San Giovanni (Ruoti, Italy); B) Castle of Lauria (Lauria, Italy)

3.1. Quality of the equipment:
The first of the variables includes the instruments used to acquire, process and manage data from the drone. An important role is played by the type of drone used and its characteristics (fixed wing,
multi-rotor, autonomy in flight, range of action, etc.), by the quality and type (Fig. 4) of sensor mounted (resolution, bands perceived in the case of a multispectral chamber, etc.). The planning of the acquisition work is strictly connected to the type of configuration possessed and it is a fundamental operation in order to potentially perform the best survey. For example, the resolution of the photos depends on the quality of the sensor and the flight height, consequently the better the sensor, the higher the height at which the drone can be pushed, which also allows to cover more hectares in less time.

![Different type of camera](image)

**Figure 4.** Different type of camera (drone camera, reflex, compact camera, action cam)

Therefore, low camera quality and limited flight range require longer acquisition times. Furthermore, the quality of the images in resolution affects the quality level of the UAV 3d models. In the processing and management of data from drones, the type of PC used has a significant impact. High-performance computers reduce processing times and work with more incoming data (photos), which most of the time implies better results in the development of 3d model, DEM and orthophoto. Dedicated video cards, latest generation processors, RAM, are essential components that should not be underestimated for working with millions of points (Point Cloud) or with extremely complex and virtually heavy 3D models.

### 3.2. Type of equipment

Thanks to drones and photogrammetry, it is possible to generate the 3D model of an area or view landscape and archeological site from different points. However, in aerial images taken with normal cameras it is not possible to observe what is underneath woods and forests; other times the archaeological features are not read on images taken with RGB cameras. These problem can be overcome by using the LiDAR and multispectral camera. In fact, some drones, thanks to their particular configurations and maximum payload, can mount LiDAR (a tool that consents to digitally filter the vegetation) and sensors such as thermal cameras, multispectral or hyperspectral sensors (to detect beyond the visible spectrum). These equipments allow to perform a series of analyzes and to deepen the knowledge of landscape and archaeological sites, often impossible to do with RGB camera.

### 3.3. Survey method

As previously anticipated, the planning of flights is the basis of a good survey and there are several factors to consider. These include the quality of the sensor, the type of drone, the area to be taken, the light of the sun (orientation of the rays, the shadows, presence of clouds, etc.), the weather conditions, the morphology of the terrain, the height and distance of the drone from the object to be detected, the camera orientation, the photo taken in the photogrammetric coverage mode (nadiral, oblique, high altitudes, close-up, etc.) to create the 3d model. For example, a small number of photos, taken from a
single perspective or from too high heights, with different lighting conditions, often do not allow the creation of precise 3D models with a high level of detail. Instead, a correct photogrammetric coverage, carried out in a condition of diffused light by a drone equipped with a high resolution camera, allows to obtain excellent results. For example, in the case study brought in support of the thesis is possible to observe how has improved the point cloud of the castle of Uggiano (Ferrandina, Italy) as the number of photos increases (Fig. 5).

3.4. Data processing method
Another variable to be taken into strong consideration, closely related to the computing power of the PC (processor, RAM, CPU, video card, etc.), is related to the quality of the processing of images taken by drone. An excellent acquisition if not supported by an equally excellent processing can prove useless. Low parameters in the processing of the orientation of the photos, in the creation of point clouds or mesh, can significantly affect the goodness of the 3D model and the related derivatives (DEM, orthophotos), revealing a real limit in the archaeological interpretation of its own due to the low level of processed products. Starting from the same photo dataset was elaborated the 3d model of the Necropolis of San Nicola (Ferrandina, Italy) with high and low parameters during the workflow (orientament of the images, point cloud, mesh, etc.). The quality of the 3d model is visibly different with considerable increase and loss of archaeological data. (Fig. 6).

3.5. Data acquisition period
Another important variable is related to the period of data acquisition from UAV. As from literature, the archaeological interpretation is strongly connected to the geology of the land, to vegetation, to the best periods for the reading of crop marks or soil marks, for example. The same can be said, in part, now with 3d models, trying to identify the best period and condition of the land in order to be able to
make the acquisition based, for example, on the type of cultivation of the land (cultivated or plowed field). In fact, some archaeological territorial contexts can be more evident if taken up after plowing the land or before harvesting. This is the case, for example, of the countryside of Sant’Antonio (Ferrandina, Italy) where several archaeological sites are present, some crop marks can be observed at certain times of the year (Fig. 7).

3.6. Correct data management
Aerial photos, 3D models and DEMs in particular, require some experience in their management by the archaeologist, in addition to the knowledge of the software that allows us to observe and interrogate them. Often, the final files are loaded directly by the user into GIS platforms and observed as they were produced. In reality, there are some tools that allow us to modify some parameters (light exposure, azimuth, number of light points, etc.), to apply masks or some particular filters, such as the Sky View Factor (SFV) [10]. For example, by comparing the orthophoto and the DEM of El Palacio de Taurichumpi (Pachacamac, Peru), it is possible to observe different structures only in the digital elevation model (Fig. 8).

3.7. Experience and interpretation skills
The last variable is linked to the experience of the archaeologist in this field of proximity remote sensing research. Know-how that must be indispensable from the understanding of all the variables
previously mentioned and from an experience gained in the field of classic remote sensing, the archaeology of landscapes and ancient topography.

4. Conclusions
The contribution of drones and photogrammetry in archaeology is very important and allows us to improve scientific research. These tools and methodologies, even if innovative, require a thorough knowledge of data acquisition, management and interpretation techniques. The archaeologist, as demonstrated in this article, must keep in mind several variables, which are closely linked to each other and strongly influence the success of the scientific investigation. These are strictly dependent on and linked to the archaeological territorial context that is going to be investigated, which can be easy or difficult to read due to the events that have taken place after its abandonment (spoil, rake, age of the site, exploitation of the land, etc.). In the future, the creation of an operating manual for the use of drone and for the processing, management and interpretation of data is desirable.

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