An Aircraft-Based Colorimetric Application for the Aerial Exploration of Archaeological Contexts

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ABSTRACT:*The research conducted during the PhD work in post-classical archaeology on the upper Lazio region, between the municipalities of Tarquinia and Civitavecchia (Italy), has shown different perspectives on the investigation of the area through the use of new aerial remote sensing instruments in archaeologically sensitive contexts. In surface archaeological investigations, attention was drawn to the possibility of exploiting a small aerial instrument capable of reading the spectral signature of each element. By acquiring this data, it is possible to recognize the identity of each over-flown material unambiguously. This capability, which has so far only been applied in archaeology for the analysis of claddings or small artefacts, is now also being tested in the field of spatial investigations carried out in archaeological contexts that are already partially known and which show a recurrence in the building materials used. The development of a remotely piloted aerial system that integrates multi-band cameras is enabling a different aerial observation of the archaeological context of Cencelle (Tarquinia, Italy) through the understanding of its construction materials rather than its forms. In fact, the chronological indication of the life phases of a site cannot only be deduced from the indications provided by the horizontal layers and the ceramic fragments found in them, but also the materials used in the construction of the buildings themselves can be a valid archaeological phase tracer, at least in certain geographical contexts.*

KEYWORDS –*Remote Sensing, Colorimetry, Spectroscopic and Spectrometric techniques, Topography, Medieval Archeology*

I. INTRODUCTION

The project is the result of interdisciplinary research between archaeology and colorimetry, conducted by thechair of Christian and Medieval Archaeology at the Sapienza University of Rome and Profilocolore (https://www.profilocolore.com/it/spectral-imaging-systems-it/), a srl specialized in the development of Multispectral Imaging systems with high precision colorimetric and radiometric accuracy, which led to the realization of an airborne system capable of reading the spectral signature of each element within a drone frame. The project was supported by a Type 2 Start-up Research Grant from the University of Rome 'Sapienza' obtained in November 2021, by Federica Vacatello (project leader and PhD in Archaeology at the Department of Antiquity Sciences at the University of Rome 'Sapienza'), who coordinated an interdisciplinary research team composed of archaeologists, physicists and color engineers who worked on the integration and testing of a specific aerial medium for observing matter microscopically. The system's innovation with respect to the known state of the art [1], lies mainly in the mechanical modification made to the camera and its reproduction on a micro-camera integrated in a drone capable of reading the reflectance of each photographed object and allowing the identity of each element to be recognized unambiguously.This capability, hitherto only applied in archaeology for the analysis of claddings orof small artefacts, can also be applied in the context of spatial investigations in already partially known contexts, which show a recurrence in the construction materials used. In this way, it is possible to give an initial reading even to unknown sites, directing future investigations in areas not yet the subject of specific studies.

II. STATE OF ART

The research is part of a field of international studies where the use of remote sensing with UAV (Unmanned Aerial Vehicles) technologies and optical instruments for photometric and colorimetric measurements is increasingly widespread, not only for engineering, architectural, geological, and environmental

Figure 1: *Customization of the drone: on the left, the two GPS-enhanced micro-cameras with two multiband-pass optical filters and their integration with a DJI Mavic 3, on the right.*

surveys but also for archaeological ones. In fact, observing an object at a distance, immediately grasping its intrinsic information, makes it possible to verify more quickly the nature of what is being observed. This speed derives essentially from the very characteristic of color, which constitutes a physical property of objects and not just a phenomenal experience of the observer, and as such can be subjected to precise criteria of measurability and reproducibility [2]. The potential contained in multi- and hyper-spectral remote sensing images has globally promoted the development of a growing interest in their use as tools to support traditional archaeological research.In fact, there are numerous international projects that exploit this method of investigation for the analysis of satellite images for archaeological purposes [3]. Italian investigations, such as the multispectral analyses on the pre-protohistoric context of Fratta Polesine[4]; the examination of archaeological traces on the territory of Aquileia with a MIVIS sensor [5]or all the studies in Yemen and Peru conducted with the aid of colorimetric techniques for the interpretation of remote sensing images [6], are part of this line of research. By means of spectral arithmetic operations, the processes of addition, subtraction, multiplication, and division of the pixel values of one channel by the corresponding values of another channel, on the Red and near-infrared bands, it is possible to monitor the health of vegetation based on a simple color difference. Similarly, the study of bare soil variations (damp mark) with multispectral techniques can indicate the presence of buried structures in the subsoil based on a color difference due to the soil's capacity to absorb water and moisture.Such indices have found wide use in archaeological research [3] since, by providing an accurate record of information, they allow a precise definition of the absorption characteristics of a variety of materials existing on the earth's surface and the extraction of the chemical-physical characteristics of all elements present in the scan. In contrast, the use of colorimetric investigation techniques in the broader field of cultural heritage has been recorded mainly for non-invasive

diagnostics [7], for the recognition of different color pigments [8] or for monitoring pigment alterations. In all cases, however, these applications are still in the experimental research phase aimed at defining reference standards. What results is the absence of the application of colorimetric investigation techniques at a reduced spatial scale, such as that of individual archaeological contexts, which would allow for a quick understanding of the

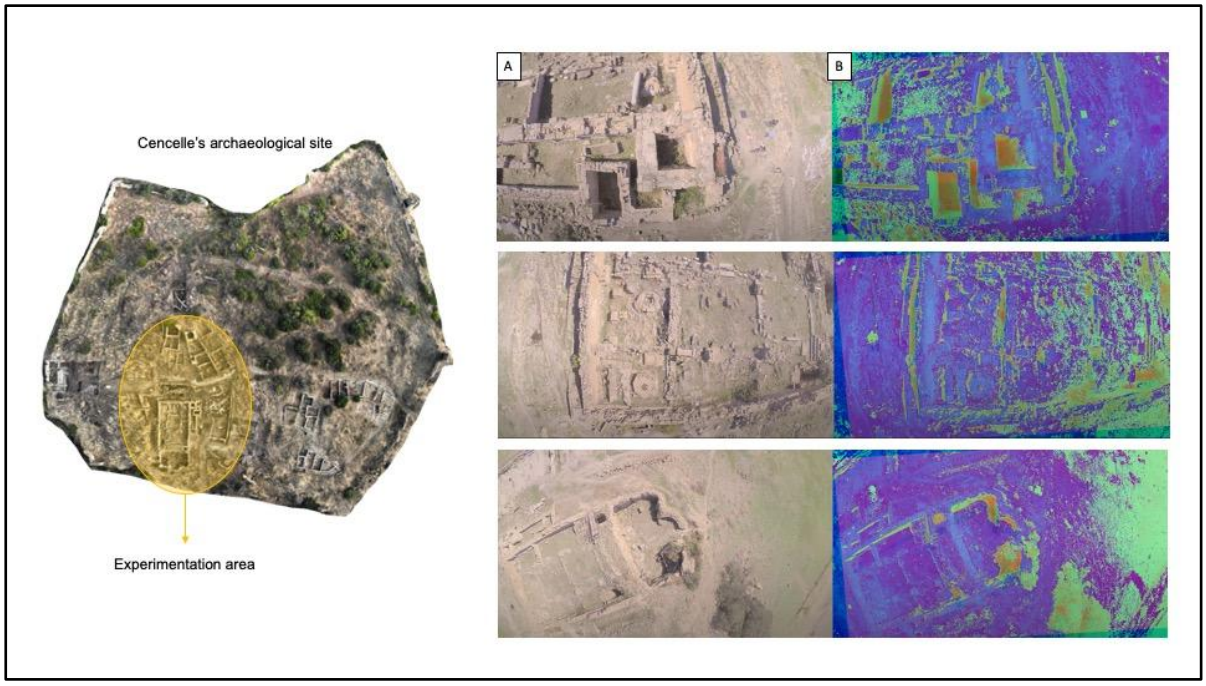

Figure 2: *Experimentation context: on the left the RGB (A) and NDVI (B) view of St. Peter's Church in the medieval town of Cencelle (Tarquinia, Italy).*

nature of the materials visible on the surface, based on the spectral response of each element.

III. DRONE CUSTOMIZATION

The prototype consists of a light commercial drone customized with two micro-cameras,typologically identical, with broadband sensitivity from ultraviolet to infrared (Fig.1). The optical modification is derived from Profilocolore's CAMGIC technology, which consists of the acquisition of the scene through two multiband-pass optical filters with optimized spectral transmittances to obtain, through SpectraPick, a calibration software based on artificial intelligence, 7 spectral bands from 300 to 1000 nanometers, a CIELAB color image and an NDVI image [9]. In this way, the instrument can highlight spectral and colorimetric characteristics of what is being imaged (plants, buildings, materials, and people) that cannot otherwise be determined in the visible light spectrum alone.The resolution of the images obtained is the original resolution of the cameras used, ranging from full HD up to tens of megapixel images depending on the sensor. The richness of the colorimetry and spectral bands produced by the Camgic system, together with a radiometric accuracy of 99% guaranteed by the SpectraPick calibration system developed by Profilocolore, makes it possible to calculate more than a hundred different indices useful in analyzing the territory and its use. This mode is equivalent to what can be done through Remote Sensing by satellite, but with much higher spatial resolutions, on the order of a centimeters. The system, designed to speed up surface archaeological surveys, is also a highly functional tool for other professional fields, as it can also be applied in agriculture, engineering, geology, and architectural restoration.

IV. TERRITORY TESTS

Following an initial laboratory experimentation phase, the system was tested on the areaof the medieval settlement of Cencelle (Tarquinia, Italy), an archaeological excavation that is part of the "Grandi Scavi" Sapienza programme

conducted under the scientific direction of Prof. Giorgia Maria Annoscia[10]. The site, being extensively studied also in terms of its construction chemical composition of the individual materials and their spectral answers. The experimentation demonstrated the efficiency of the engineeredsystem not only in-flight stability, but also in the ability to faithfully describe the identity of all objects within each frame using NDVI visualization alone.Already within the frames obtained, it is possible to distinguish different color scales in which the variation of colors results from the change of the different materials framed by the camera lens (vegetation, mould, different types of stone and lime) rather than from an altimetric difference, as in the case of a common digital terrain model. In two different scale levels, one can observe the differences between low vegetation, in the green scales, tuffaceous stone of different types (black and yellow), in the blue scales, mortar, in the purple scales and shrub-like vegetation in the red scales (Fig.2).The images acquired by the small prototype are enabling the creation of a database of spectral signatures known for the Cencelle context for the remote sensing identification of similar or identical marks in the upper Lazio region outside the site, to map the yet unknown archaeological marks in the area, only by exploiting a different observation system. Each material in fact, depending on the time of exposure to sunlight, will return a unique spectral signature that will be able to distinguish an older structure from a more modern one. In this way, the spectral signatures acquired in the experimental context are used for comparison to identify other contexts that arechronologically coeval and structurally like the test site.

V. CONCLUSION

The innovation of the engineered system consists mainly in the mechanical modification made to the camera and its reproduction on a micro-camera integrated in a drone capable of reading the reflectance of each photographed object, allowing the identity of each element to be recognized unambiguously. This capability, which until now has only been applied in archaeology for the analysis of claddings or small artefacts, can also be applied in the context of territorial investigations in already partially known contexts, which show a recurrence in the construction materials used. In this way, it is possible to give an early reading even to unknown sites, directing future investigations in materials, was an excellent test field in which to test the accuracy of the data acquired based on the

areas not yet the subject of specific studies.

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