Mapping landscape components by UAV multispectral surveying platform

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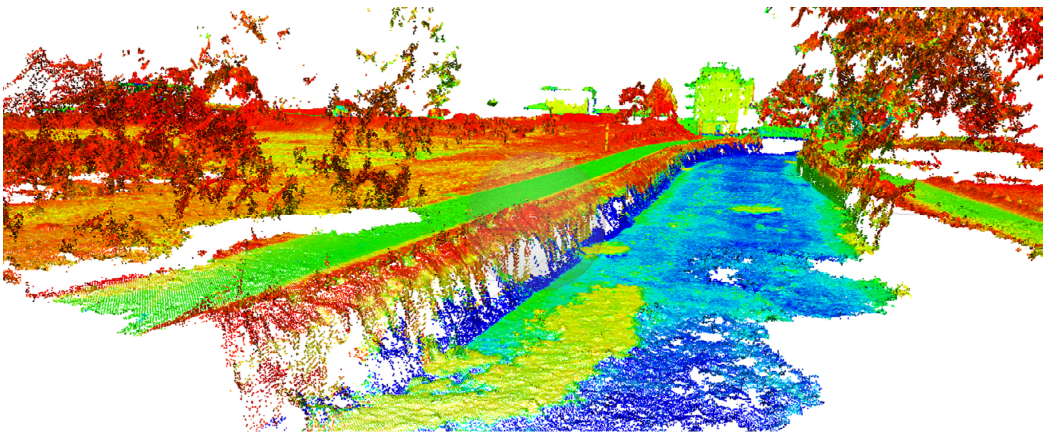
Abstract

This research explores the potential of the Unmanned Aircraft Vehicles (UAV) multispectral surveying platform for mapping landscape components, particularly referring to open spaces that are localized outside the main urban settlements. In the landscape research field, while 2D cartography is conventionally recognized as a tool for landscape representation, the emerging role of high-accuracy 3D representations, derived by UAV data acquisitions, is not yet fully clarified and expressed. By analyzing a real case study located in Cernusco sul Naviglio (north-east of Milan), the research shows how the UAV multispectral platform can be performed for collecting, visualizing, interpreting, and mapping landscape components, by exploiting Ultra-High-Resolution (UHR) data. The selected study area allows to consider heterogeneous objects that are recognizable, at the landscape scale, as areal entities (green areas, vegetated areas, agricultural fields), linear entities (waterways, infrastructure, pedestrian and cycling paths), and punctual entities (single buildings and single trees). The research shows how different kinds of representation can support the analysis and interpretation of landscape components from point clouds to final outputs (3D Mesh, DEM, and Orthomosaic), also by exploiting the potential of geometric aspects and material attributes by multispectral bands (i.e. vegetation indices). The research also discusses whether (1) the higher accuracy of spatial information, (2) the detection of objects at a finer scale, and (3) the making of 3D models derived by photogrammetric processing, can effectively support landscape-scale analysis and applications.

Keywords
mapping, landscape, UAV, multispectral imagery, aerial survey



An example of UAV mapping applied to landscape scale. Elaboration by the authors.

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Introduction

In the last decades, Remote Sensing (RS) applications resulting from Unmanned Aircraft Vehicles (UAV) have enormously increased across many different sectors (security, agriculture, forestry, earth observation, industry, energy, and communications) [European Commission, 2007], to support decisions and design strategies. This research investigates the potential of the UAV surveying platform in the field of landscape representation, by exploiting Ultra-High-Resolution (UHR) multispectral data acquisition. While cartographic representations are conventionally recognized as effective tools for investigating landscape features in the bi-dimensional form [Pandakovic et al. 2013], providing spatial information about the places with a "filter" that reveals a certain degree of approximation of the observed objects related to the landscape scale, referring both to historical maps and geographic information system in fig. 1 (fig. 1), the UAV platform, enables to building of high-accuracy three-dimensional survey models, obtained by UHR data (less than 10 cm), that require major efforts in discretization, interpretation and classification of spatial entities.
In the RS field, while satellite and airborne acquisition provide High-Resolution (HR) and Very-High-Resolution (VHR) data, which allow to capture of spatial data on large territorial portions, UAV acquisition, due to the low flight altitude, provides very dense and detailed data about the surveyed objects, which does not correspond in all cases to an increase of the level of information and knowledge [Yao H. et al. 2019]. So, in this perspective, some research questions have emerged. How can the UAV surveying platform contribute to the detection of landscape components? How can 3D models by the UAV surveying platform increase the knowledge level about landscape?

Fig. 1. On the left: Historical map of the study area. Teresian Cadastre, series: "Mappe Piane, Prima Serie, Mappe di Attivazione, 1720-1760". Source: Archivio di Stato di Milano. Accessed online: 30th January 2024. Elaboration by the authors. On the right: Map of the study area, with evidence of the historical city center of Cernusco sul Naviglio, the Naviglio della Martesana, and the M2 green subway line. Elaboration by the authors.

Such questions find a potential solution in the procedure outlined in this paper; however, it is crucial to frame the problem with consideration for the general issue that information technology compels to face: the level of precision, exactness, and accuracy of information required to define landscape features.
In general, a proper balance must be meticulously weighed throughout the process of interpreting and comprehending the observed phenomena. Beginning with the initial phases, where data and information serve as inputs for the analysis based on a quantitative approach, the progression should lead to the final output, in terms of knowledge - the most relevant aim of the interpretative process - which should consist of a synthetic, qualitative description and representation, that must be effectively useful to be applied in a design-oriented strategy.

Study area

The research has been applied to the study area of Cernusco sul Naviglio (north-east of Milan), by analyzing a peripheral area characterized by a complex landscape that is innervated by linear components such as the historical canal of Naviglio della Martesana, the M2 green subway line, pedestrian and cycling paths, areal entities such as green areas, agricultural fields, vegetated areas, and by punctual entities such as single buildings and single trees.
The study area has also been analyzed by considering the historical map of Teresian Cadastre (Archivio di Stato di Milano) (fig. 1, on the left), which shows on the one hand, the spatial configuration of town and its surroundings between 1720 and 1760, which makes evident the location of the historical center of Cernusco sul Naviglio, completely developed on the right bank of the canal, and on the other hand the study area under investigation which maintained approximately the same spatial configuration in terms of land-uses, with the addition of M2 green metro line built in 1972 on the southern side, and surrounding buildings on the east side (fig.1, on the right).

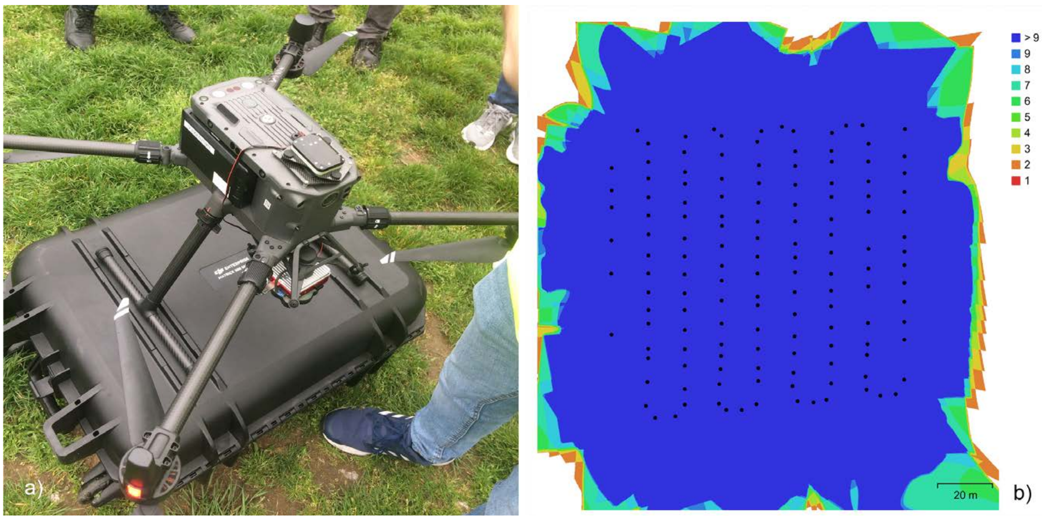

Fig. 2. On the left: Image of Drone DJI Matrice Altum Multispectral with Altum Multispectral Camera. Picture by authors; on the right: Map of the surveyed study area, with evidence of camera locations over the flight and image overlap. Elaboration by the authors.

Materials and Method

The UAV flight was conducted in the study area of Cernusco sul Naviglio, on 18th April 2023, with the Drone DJI Matrice 300 RTK, by installing as payload the Micasense Altum Multispectral camera, which acquires spatial data into 6 different bands (Blue, Green, Red, Red Edge, Near Infrared and Long-Wave Infrared - Thermal) (fig. 2, on the left). The map of the surveyed area (fig.2, on the right) shows the 144 camera locations, from where are captured 144 shots multiplied by 6 spectral bands, which generate the total amount of 864 images and the image overlap that show how images cover the study area. The flight altitude was 52,5 m, and the ground resolution was 2,26 cm/px. The image resolution for the spectral bands from the first to fifth band is 2064 x 1544 px (3.2 MPixels), and 160 x 120 px for the sixth (0,01 k); the focal length is 7,8 mm for the spectral bands and 1,77 mm for thermal.
One of the goals of this research is to verify how the UAV surveying platform can contribute to the analysis and interpretation of landscape components. The UAV-based data acquisition is the base to start more efficient and faster photogrammetric and videogrammetric workflows [Parrinello et al. 2022] which enable the making of 3D standard products such as Point Clouds, Meshes, Digital Surface Models (DSM), and 2D Orthomosaics. In this research, the images acquired by the UAV flight were processed by Agisoft Metashape Pro

software, by aligning 139 of 144 images correctly, generating 1.098.601 tie points, which are the link between images and 3D relative positioning. The next step to image alignment was the building of high accuracy dense points cloud (12.203.903 points), which provides both a 3D and 2D orthogonal visualization of the study area (fig. 3). As compared to cartographic representations the points cloud gives the chance to get a high-accuracy 3D visualization of the landscape (Real color RGB), which shows how landscape components are distributed in the space, and their detailed features (geometrical and material). In this research, the standard RGB bands were enriched, through the multispectral camera, of Red Edge, Near Infrared (NIR), and Long-Wave Infrared (LWIR) bands, that supply additional information to the landscape survey (i.e. health vegetation status), which are not directly visible to human eyes, but that can be detected by infrared bands and that can be relevant for landscape analysis and interpretation. In this case study, the NDVI vegetation index, was computed as the normalized difference of NIR and Red bands [Tucker 1979; Pettorelli et al. 2005], with the aim to contribute to the performance of landscape components classification. In the field of landscape mapping even integrated approaches, which combine LiDAR and Multispectral data acquisition, are emerging as way to perform automatic classification of landscape components [Cao et al., 2022]. In this perspective, the points cloud classification was carried out by considering two main criteria, geometrical and material reflectance, combined into a semi-automatic approach, which results from three different contributions: (1) the automatic algorithm of the software for point classification (six classes available: ground, high vegetation, building, road surface, man-made object); (2) the automatic points selection by colors, exploiting the sharp contrast of NDVI visualization, which values ranges between -1 and +1, and allow detecting specific objects (i.e. green for pedestrian and cycling paths, cyan and blue for the water of the canal, dark red for shrubs and trees); (3) the manual points selection, performed by using RGB, NDVI and elevation visualizations of the points cloud (fig. 3). Moreover, the manual selection was performed by exploiting perspective and orthogonal views which allows an effective selection of points to assign to the classes.

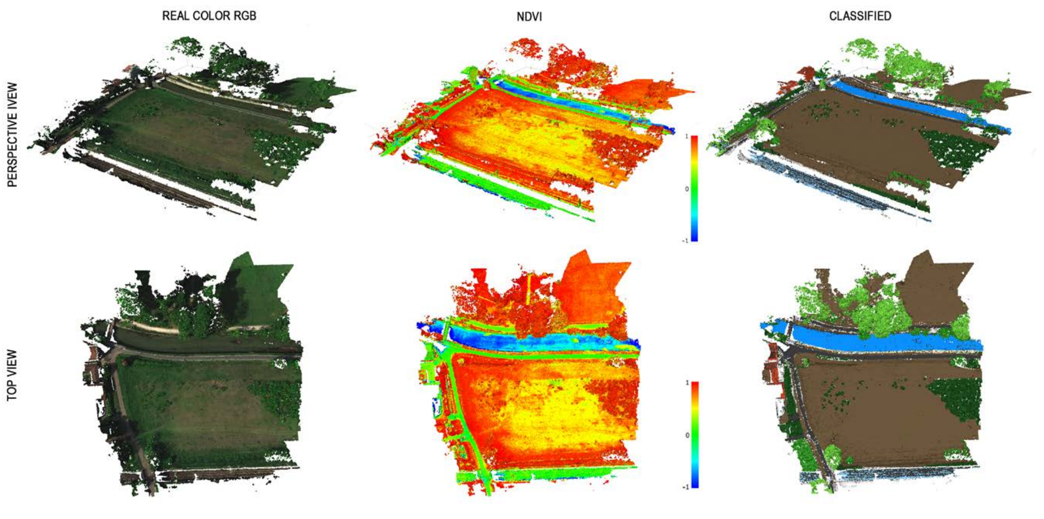

Fig. 3. Synoptic table of point clouds images (perspective view and top view), from left to right: real colors (RGB), NDVI, and classified visualizations. Elaborations by A. Scandiffio.

The classified points cloud as visible in fig. 3, enables the visualization of 9 classes (ground, low, medium, and high vegetation, water, building, rail, road surface, and man-made objects). In the next rows, it will be analyzed the classified points cloud, class by class, highlighting, criteria, selection method, and object types included in each class (fig. 4).

The ground was classified by exploiting the software automatic ground classifier, refined by manual selection which allow to extract water and rail. The vegetation was grouped into three main classes, according to the height of the vegetation on the ground level.

Low vegetation, such as shurbs, has been defined in the range between zero and two meters; medium vegetation between two meters and ten meters; and high vegetation over ten meters. Water in the canal was classified by exploiting the lower values in the NDVI color visualization, in the range between -0,5 and -1, visible as cyan and blue on the map. Buildings were classified through RGB color visualization, due to the distinctive color of the roofs, refined by manual selection for including part of the facades. Rail and road surfaces (pedestrian and cycling paths along the riverbanks) were detected by intermediate values (around zero) in the NDVI palette, which are sharply visible and detectable by the green color. Man-made objects including walls, fences, artificial riverbanks, and the small bridge on the canal were manually selected because they are "interface" objects, often mixed with low vegetation, and complex enough to be classified automatically.
The classified point clouds can be used to select relevant classes and extract the Digital Terrain Model (DTM) from the whole Digital Elevation Model (DEM), which includes terrain and overlaying objects.

CLASSES	CRITERIA	SELECTION METHOD	OBJECT TYPES
Ground	Geometrical	Automatic/Manual	Soil, grass
Low vegetation	Geometrical	Elevation/ colors by NDVI	Shrubs, hedges (0-2 m)
Medium vegetation	Geometrical	Elevation/ colors by NDVI	Trees (height 2-10 m)
High vegetation	Geometrical	Elevation/ colors by NDVI	Trees (height > 10 m)
Water	Reflectance material	Colors by NDVI	Water
Building	Geometrical	Colors by RGB/ Manual	Buildings, roofs, façade
Rail	Geometrical	Colors by NDVI/ Manual	Tracks
Road surface	Reflectance material	Colors by NDVI	Pedestrian/cycling paths
Man-made object	Geometrical	Manual	Bridge, wall, fence, riverbank

Fig. 4. Point clouds classification, criteria, and selection methods. Elaboration by the authors.

Outcomes

The standardization of the photogrammetric processes within the software enables the making of high-accuracy products such as textured 3D mesh, Digital Elevation Models (DEM), and 2D orthomosaics, which allow landscape visualization and interpretation. In this research, the main outcomes of the UAV survey are the 3D mesh and 2D orthomosaic which are expressed through the RGB and NDVI visualizations (fig. 4). The process of texturing applied both to the 3D mesh and orthomosaic increases the level of detail of the objects, which can be visualized realistically.
The 3D mesh obtained by converting the point clouds into triangular surfaces (the points become the vertexes of the triangular surfaces of the mesh) enables the real color visualization of the landscape. In this case, on the one hand, the geometrical conversion, from point to surface, enables to build of a continuous and refined 3D model, and on the other hand, in terms of material, the 3D mesh enables the visualization of material consistency (fig. 5). In the mesh, each 3D single landscape component classified by the point clouds (i.e. canal, building, low, medium, high vegetation, pedestrian and cycling paths) can be extracted to be used separately in other 3D modeling software for other different purposes (i.e. modeling, rendering).
The 2D orthomosaic is a standard photogrammetric product that enables the orthogonal visualization of the landscape from the top view, performed by deleting perspective distortions from the images. As it is visible in fig. 5 (fig. 5), the orthomosaic is a 6 bands UHR georeferenced image (GSD 2,26 cm/px), which can be used for different cartographic purposes (i.e. making a detailed RGB base map of the area or thematic map). Moreover, the infrared bands in the orthomosaic can be easily combined to compute vegetation indices, which are helpful for several applications in the field of agriculture, precision farming, land-use classification, landscape design and others.

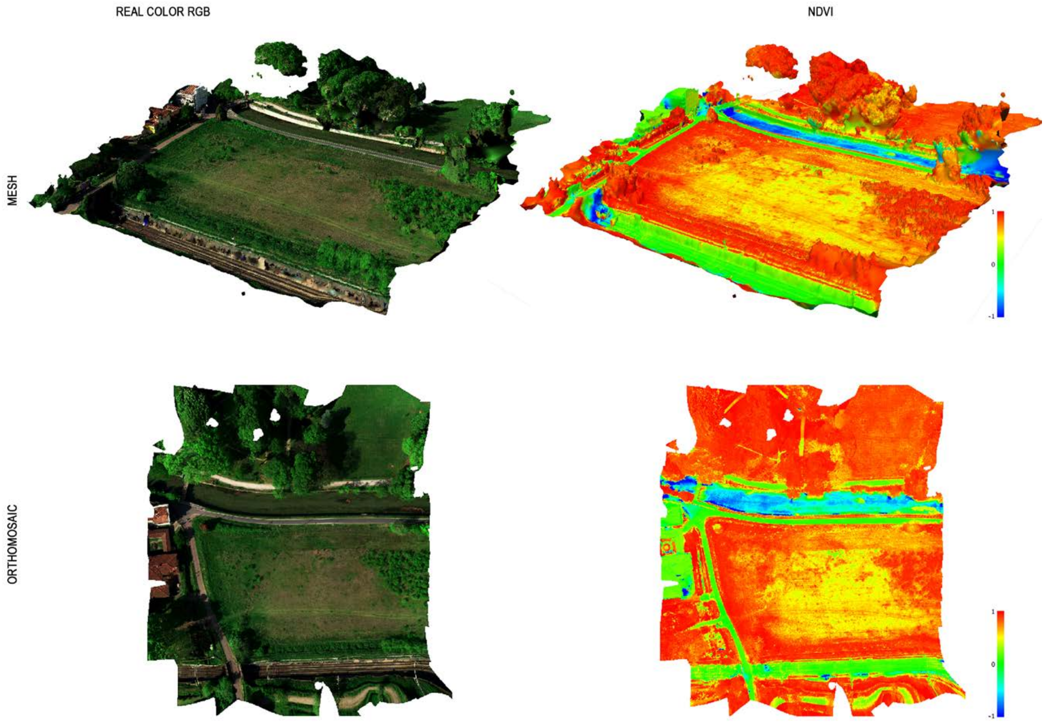

Fig. 5. 3D mesh and orthomosaic, shown in the real color visualization and NDVI. Elaborations by A. Scandiffio.

Discussion and conclusions

In this paragraph, some advantages and disadvantages of UAV multispectral platform surveying are discussed by targeting landscape applications.
The main advantages of a UAV-based platform are mostly related to the UHR images that allow the detection of landscape components. Firstly, compared to satellite, airborne data acquisition, land-use maps, and technical cartography, the UAV platform enables the recognition and classification of additional landscape components, that are detectable at a finer scale (i.e. shrubs, hedges, tree types, grass distribution on a field), but also to capture the specific material features of mineral components (i.e. roads and paths pavement, roof materials, lighting plants, electricity plants for railway). Secondly, the UAV-based data acquisition enables to perform the photogrammetric processes that can be used to make both UHR 3D mesh and 2D orthomosaics, which are much more accurate than satellite imagery and traditional cartographical products.
Some limitations are related to the extreme amount of data, that needs to be discretized and smoothed to be correctly classified as landscape components. The main problems are related to the automatic recognition of specific objects in the point clouds classification, which is related to their complex shape (i.e. trees, shrubs) and to the role of interface of some objects (i.e. walls, hedges, riverbanks), that most of all, in the real consistency, are mixed to vegetation and difficult to detect as a single object. Furthermore, the UAV-based platform, to perform a complete 3D model, needs to be combined with a complementary survey tool (i.e. terrestrial Lidar), which enables to detection of the objects from a ground perspective.
Finally, the UAV platforms seem to supply a promising contribution to the landscape representation research field, to get high-accuracy surveys, but that requires further efforts, especially in the software industry to manipulate and control different levels of discretization of spatial information in relation, both to the objects types, both referring to the scales, going through the process of the analysis to the synthesis.

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All the authors shared the principles and the research topics presented in the article. However, the paragraph titled "Introduction" was written by both authors, the paragraphs "Study area" and "Materials and Method" were written by A. Scandiffio, the paragraphs titled, "Outcomes" and "Discussion and Conclusion" were jointly written by both authors.

References

Archivio di Stato di Milano, Catasto Teresiano, Mappe Piane, Prima Serie, Mappe di Attivazione. Comune Censurario: Cernusco 1720-1760. <https://www.archiviodigitale.icar.beniculturali.it/it/185/ricerca/detail/657382#viewer> (accesssed15.07.2024).

Chao T. E. M., Antuono G., Vindrola P. G., D'agostino P. (2022). Image-based segmentation and modelling of terraced landscapes. In S. Parrinello, S. Barba, A. Di Fillippo, A. Dell'Amico, *D-Site. Drones. System of information on cultural heritage for a spatial and social investigation*, Vol. 2, pp. 422-431. Pavia: Pavia University Press.

Cureton P. (2021). *Drone Futures: UAS in Landscape and Urban Design*. Londra: Routledge.

European Commission (2007), *Study Analysing the Current Activities in the Field of UAV.* ENTR/2007/065. 2007. Available online: <https://ec.europa.eu/docsroom/documents/1706/attachments/1/translations/en/renditions/native> (accessed 15.07.2024).

Pandkovic D., Dal Sasso A. (2013). *Saper vedere il paesaggio*, pp. 218-22. Novara: Città Studi.

Parrinello S., Dell'Amico A., (2022). Drones and digital innovation: a new scenario in digital dimension. In S. Parrinello, S. Barba, A. Di Fillippo, A. Dell'Amico, *D-Site. Drones. System of information on cultural heritage for a spatial and social investigation*, Vol. 2, pp. 17-25. Pavia: Pavia University Press.

Pettorelli N., Vik J.O., Mysterud A., Gaillard J.-M., Tucker C.J., Stenseth N.C. (2005). Using the Satellite-Derived NDVI to Assess Ecological Responses to Environmental Change. In *Trends in Ecology and Evolution*, Vol. 20, issue 9, pp. 503–510. <https://doi.org/10.1016/j.tree.2005.05.011>

Tal D., Altschuld J. (2021), *Drone Technology in Architecture, Engineering, and Construction.* Hoboken: Wiley.

Tucker C. J., (1979). Red and Photographic Infrared Linear Combinations for Monitoring Vegetation. In *Remote Sensing of Environment*, Vol. 8, Issue 2, pp. 127-150. <https://doi.org/10.1016/0034-4257(79)90013-0>

Yao H., Qin R., Chen X. (2019) Unmanned Aerial Vehicle for Remote Sensing Applications - A Review. In *Remote Sens.* Vol. 11, Issue 12, 1443. <https://doi.org/10.3390/rs11121443>

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