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Landscape forms through drone documentation: rediscovering continuity of Torto river in Braga District, Portugal

Abstract: This article proposes a proof of concept related to a methodology that uses an unmanned aircraft vehicles (UAV) as an investigation tool in landscape planning, which results can be used also in archaeology, cultural landscape, and heritage studies, to create a multidimensional approach for understanding relations between valuable assets and preserve fundamental qualities of the landscape. It is evaluated if UAV is appropriate as a research tool (through accessibility of equipment, software, and workflows of its application) capable of providing multidimensional views of the landscape that could be used to anticipate planning decisions. As an example, the Torto River, located in Braga, Portugal, starting from its intersection with Roman Via XIX, was studied.
Research aims to show that the drone surveying can lead to raised awareness on disappearing continuity of landscape elements, and the value of their spatial relationships, which are not taken into consideration in development of places like researched area neighbouring nuclei of S. Frutuoso and Dume, nearby popular pilgrimage trail Camino de Santiago.
The possibility of identifying and reflecting on the elements that ensure continuity of landscape is noted through videography recorded based on the visual line of sight (VLOS) mode. The research explores a variety of conditions that should be considered when preparing for research and recording chosen information (as local regulations, weather conditions, expected outputs), proposing a methodology of flight planning and execution with the most optimal setups, including –15° angle for capturing landscape elements and their relationship, and – 90° for photogrammetry and videogrammetry (here captured in maximal altitudes allowed for the research area, not overstepping 75 and 120 m limit).

Key words: UAV photogrammetry, videogrammetry, landscape, Braga, survey

Introduction

Aim and needs of the research

The proof of concept aims to explore an unmanned aerial system (UAS) as an accessible tool for landscape studies, enabling gathering detailed knowledge of the territory. This article was based on the need to analyse various setups of UAVs and state the most optimal settings. Proposed workflow is meant for simplifying implementation of UAVs in the research for architects, archaeologists, urban planners and researchers, and its novelty lays in presenting ready-to-use solutions of UAV settings, depending on the demanded outputs.

Novelty of this qualitative research lays in using commercial UAVs and made by it aerial videos in landscape studies, in order to enrich the field with new perspective on the territory, observed in undisturbed, continuous way. Drone is seen as a tool that allows insight in various qualities of surroundings, and compared to ground access, allows non-fragmented vision thanks to minimal number of obstacles on its way. UAV is researched here as an effective tool for creating digital elevation models (DEMs), which is highly accessible, especially compared to airborne laser scanning (being high cost and time taking, and requiring professional skills and equipment).

The site was chosen because it is a territorial system marked with temporal extractions that is highly pressured by poorly planned urban development. The river landscape system, by its legibility diminishing, is progressively losing capacity to influence urban transformation.

The experience was described with videogrammetry, which is a novel, not yet researched, technique. Opposed to photogrammetry, it uses videos instead of photos to produce outputs. Here we are talking about an overall look of the landscape, its values, relations of its elements, rather than strictly technical details of videogrammetry or photogrammetry.

The main research questions were:
– How accessibility of UAVs can change ways landscape is seen, valued and protected?
– What benefits does UAV videogrammetry brings into landscape studies?
– How does the perception of the continuity of landscape elements change with different points of view?
– How can you simplify the process of flying, obtaining permits and parameterisation?

To obtain answers to the questions, methodologies were formed:
– formulating research questions and goals,
– preparation for the survey (obtaining needed authorisations and licenses),
– drone flight survey planning (planning flight paths and boundaries),
– flight execution,
– processing collected data,
– analysis of the data collected during different flights,
– summary and results preparation.

State of the art

Videography

Drone footages are seen as an accessible way of video recording which goes beyond an eye-level perception limitations, gaining popularity in non-professional use thanks to vast variety of equipment in accessible prices (Vujičić et al. 2022). Drones allow life-streaming as well as recording in various resolutions, while flying on routes controlled remotely or on pre-programmed paths. Existing research focus on videography in tourism and hospitality (M. Haanpää et al. 2020). Other, less explored, domains are environment exploration, scene reconstruction and aerial cinematography.

General drone use and policies

Policing drones is meant to shorten misuse of UAVs (Fox 2022), which can increase with growing drone accessibility. EU regulations imply common rules on UAV use in its Member States (European Commission 2022). In EU there are 3 categories of operations: open, specific, and certified. Open category is divided into A1, A2 and A3, all of which allows Flights in Visual Line of Sight (VLOS) up to 120 m and not above assembly of people. For use of drones in operations specified in each of those categories a certification of passing an online training course is required.

Portuguese law allows use up to 25 kg UAV. Heavier ones need to have a special authorisation. Beyond Visual Line of Sight (BVLOS) flights can be made on segregated airspace after the registration and obtaining special authorizations (BVLOS is not a focus of this paper). Operations must be authorised and registered at National Aeronautics Authority (AAN) and Portuguese Civil Aviation Authority (ANAC). Geographic zones which require additional allowance for operations, are set by ANAC and can be consulted on their website. In restricted areas special authorisations are required, issued by, e.g., military, maritime authorities – depending on the zone of planned flights. RPAS flights are prohibited over prisons, military facilities, governmental and police facilities, bridges, embassies, etc. Height Limit is 120 m (limit of segregated airspace) – it can be reduced in restricted zones.

Drones in urban landscape documentation and planning

Digitalisation in landscape planning is seen as way to facilitate land management, emphasize existing context, and as a tool to enhance sustainability (Perry et al. 2022), e.g. by analysing land use in national parks, which can lead to data driven approach in creating robust management plans (Szuster et al. 2020), or automatising checking conditions of the area by planned drone flights (Hu et al. 2020, Stodola et al. 2020). Researching of vast areas with UAV to map it, count users, or classify natural elements is seen as time and cost effective, with easier logistics and higher safety measures, compared to manual labour (Ancin-Murguzur et al. 2020). Data obtained through UAV photography can be later labelled and analysed through deep learning algorithms, in scope of object recognition (Szuster et al. 2020). A problem of vast UAV implementation is seen rather in prioritizing top-down activities, where local authorities need to act, rather than costs of UAV operations itself (Stöcker et al. 2022).

Drones in archaeology

Drone techniques can enrich field documentation done with classical outline drawings, by recording vast terrain in relatively short amount of time while keeping high quality of pictures or videos, which can be processed to obtain orthoimages, point clouds, or 3D meshes. Use of UAV in archaeology allows quick access to sites, which without drones are hard to reach and document, as steep terrain (Xing et al. 2018). Archaeology connected with modern survey techniques, used for archaeometry, mapping, photogrammetry, and site documentation, can be qualified to Digital Humanities – interdisciplinary area at the intersection of humanities and computing/digital technologies. Digitalisation is also pointed as a possibility in creating archaeological storytelling (Earley-Spadoni 2017), using UAVs to create narratives about landscape and heritage, which can be disseminated in a wide variety of forms, reaching vast audience thanks to use of different media (text, pictures, tactile 3D models, videos, gamified information, VR, XR – seen in initiatives as GlobalXplorer.org).

Materials and Methods

Location of the study area, geomorphologic diversity, and climate

The area of research is focused on the intersection of the Roman trail Via XIX and Torto river (fig. 1), in the municipality of Braga in the northwest of Portugal. The city was established in a plateau in the interfluve of rivers Cávado and Este (Brito et al. 2021). Within the natural compartments that structure the small basins, the unit defined by the Torto river integrates the platform that articulates the lowest altitudes of the territory, elevated up to 100 metres altitude, and the areas that today are under greater urbanistic pressure. The drainage network follows the dendritic distribution pattern that characterizes the region.

Historical sketch and ongoing urban development of the researched area

Bracara Augusta was established in 16–15 BC, during the Roman Emperor's Augustus reorganization of Hispania territory. It was the capital of Gallaecia province during Diocletian rule, and in V century the capital of the Kingdom of the Suebi.

The influence of Roman spatial planning can be seen in traces of centuriation, a grid of modules sized 20 per 20 actus – 709,6 per 709,6 metres (de Carvalho

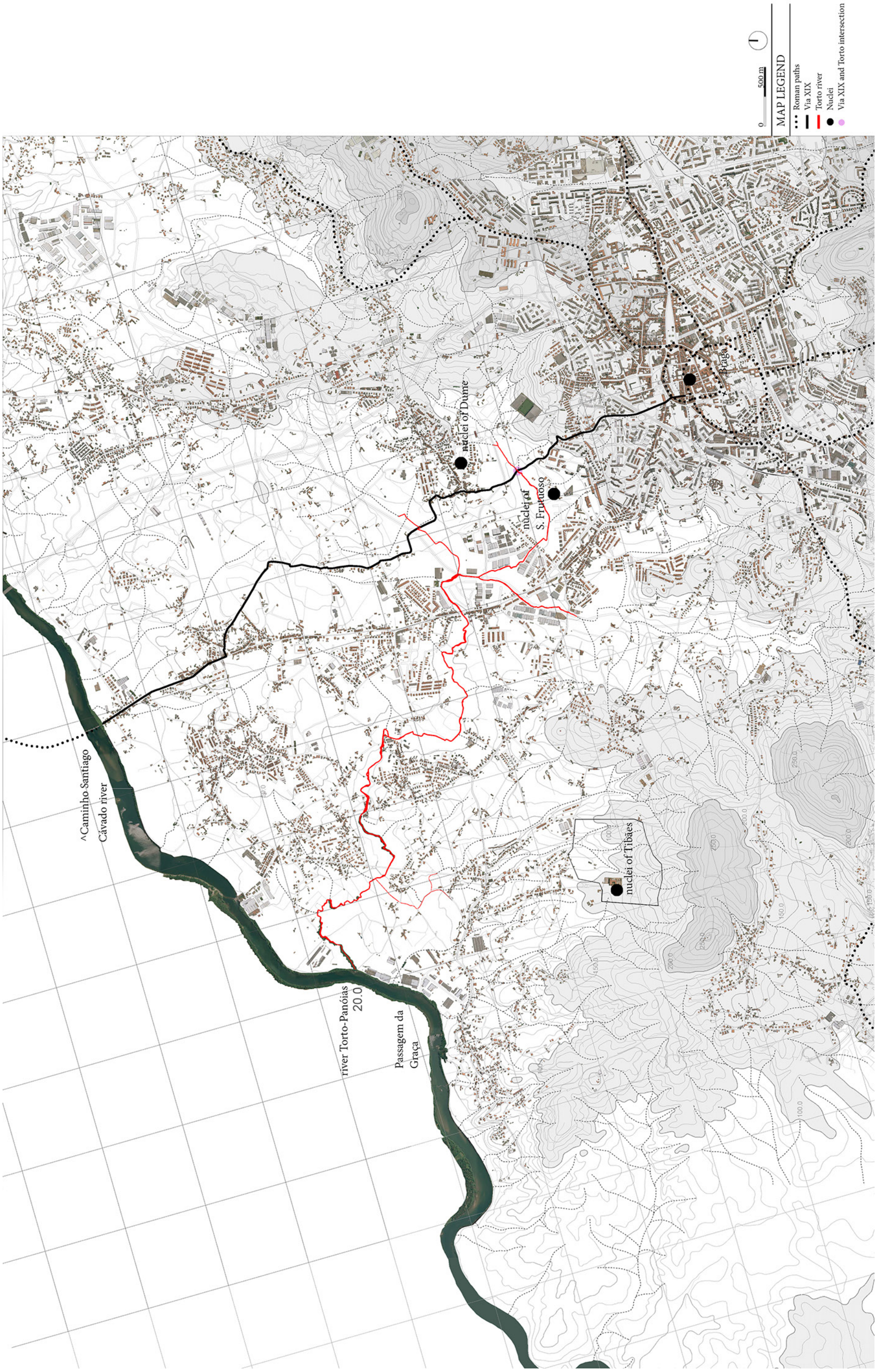

Fig. 1. Map of Braga with marked historical centre of the city and intersection of Via XIX with Torto River
Author:Sandra Brito

2008) intersecting with vital elements as routes and axis. From the six main Roman roads, that converged towards the city, one of them begun in the northern part of Braga, crossing with the research area (fig. 1). Via XIX, intersecting with Torto river, was connecting *Bracara Augusta* to *Lucus Augusti* (Lugo). This road established a structural spine, within the centuriated territory, influencing the parcelling alignments and the location of the new roman agrarian structures (Brito et al. 2021, p. 252)

In the medieval period small urban settlements started appearing in the urban periphery of Braga following Roman roads (Ribeiro, Martins 2016). Further history of the city is marked by Christian influences, to which Chapel of Saint Frutuoso (fig. 2 and 3) belongs, set on the elevation adjacent to the intersection of Torto River and Via XIX (fig.1). In the Middle Ages Via XIX connected the nuclei of S. Frutuoso and Dume with Braga. Nowadays the path is not easily readable, fragmented by new infrastructure (Ribeiro, Martins 2016). In the researched area two important territorial markers remain, with spatial and visual relationship: an archaeological site located in the parish church of S. Martinho de Dume, classified as a National Monument in 1993 (Decreto n.º 45/93 de 30 de Novembro), and the complex of S. Frutuoso and S. Francisco de Real, registered as a national monument in 1944 (Decreto n.º 33 587, de 27 de Março).

In the framing of the contemporary territory the ancient Roman road does not claim its historical condition of structuring axis (Brito at al. 2022). Braga remains until the mid-twentieth century linked to a radial road system centered in the city and the main regional connections, which begin to structure the new forms of linear occupation. As an integral part of this network, the layout of the old Roman road remains deeply obliterated and sparse. Despite its physical conformation as a continuous infrastructure, the Torto river follows a similar dynamic. Near the urban center, between the sites of Dume and S. Frutuoso, the course of the river is lost between the most recent forms of the urban development and the new industrial areas. Despite the potential of its condition as a hydrological resource, its ecologically fragile situation and the impossibility of experiencing the sense of its continuity, both longitudinally and transversally, end up hindering and obstructing possible relations of proximity. Regarding the territorial markers previously mentioned, the dynamics of recent expansion has contributed to the loss of their visibility and the sense of identity that these structures hold. The lack of a dialogue with the pre-existences and with the micro-topography dynamics is evident.

Fig. 2. View from the South to the S. Francisco church where S. Frutuoso Chapel is located, captured in second half of XX century
Source: Fontes (1989).

Fig. 3. Aerial view showing S. Frutuoso Northern façade in a wide context, showing intensive land use on the that starts surrounding this heritage site, photo made during research at Lab2PT

Project realisation

Project plan

Obtaining results for analysis is possible thanks to performing tasks:

- obtaining pilot licenses (A1 and A3 Open) and clearance to fly in the area;
- planning paths of flights and their characteristics;
- gathering digital survey of Torto river and its intersection with Via XIX (video and photography);
- processing data, creating documentation;
- analysis of documentation to check the results alignment with stated research goals.

Materials obtained during the process:

- photogrammetry and videogrammetry (based on videos);
- flight log files (used to check the accuracy of paths and flight data);
- film footage made by video editing to obtain long shots from segmented paths (flights could be performed only in VLOS, so the route had to be split);
- graphical explanation.

Chosen aircraft and software used for flight planning

The aircraft used for this research is DJI Mavic 2 Pro. Video and photo footage was performed, by planning paths in free software DJI Pilot App (V1.8.0pe) installed on the smart controller. Mission flights were planned using strategical waypoints, following Torto river course.

Flight conditions and authorisations

Flights in Braga were performed on days without precipitation, clear or partly cloudy sky, and wind not exceeding 25kph (fig. 4). Flights in the research area were indicated to the competent authorities, and data acquisition was started after receiving clearance. Each flight was agreed upon with the Airport of Braga officials. For the area of Estádio Municipal de Braga, self-authorisation was performed using a DJI verified account.

Methods of data acquisition and processing

This research focuses on civilian drone use in European Union (EU), specifically on Portugal, for research purposes, and explores UAS in scope of Remotely Piloted Aircraft Systems (RPAS), consisting of a Ground-Control Station (GCS) and a Remotely-Piloted Aircraft (RPA). Torto river run was digitally photographed (total of 280 photographs: 5472×3648 px, 72 dpi) and filmed (MOV files, 3840×2160 px, 23,98 frames/second) under natural lighting conditions using DJI Mavic 2 Pro, in 5 sessions during the period between 9.21.2022 and 11.11.2022. Timeline of works depended on weather, accessibility of pilots and equipment and airport clearance. In this period no significant differences in environmental influences over the research were noted, especially taking in consideration that flights were done only in days without precipitation nor wind stronger than 25 kph. Each JPG image has automatically recorded GPS metadata. Photos and videos taken were overlapping, to provide data needed for photogrammetry and film editing – because of VLOS measures there was no possibility of making whole path at once.

Application used for flight planning and performing was DJI Pilot, with mission flight mode chosen. Mission flights for each part of the paths were planned on imported KLM files, previously created in Google Earth. During operations it was visible that even though KLM file followed rivers course on the satellite view, in reality it was partially unmatched. Set keyframe parameters allowed focus on camera movement, since height of the flight, tilt of the camera, beginning and end of shooting (respectively 1st and last keyframe) were automatised. Path needed to be edited on site also because of obstacles not visible on virtual representation of the researched space. Number of waypoints creating the paths was edited if needed in the DJI Pilot app, depending on the river meandering and existing obstacles. Paths which were too long were split into parts by creating a copy of the KLM file and dividing it by deleting chosen waypoints. Since allowed height was max. 75 m AGL (Above Ground Level) and the drone measures only the take-off point height, we chose to set a predefined height to 65m AGL from reference take-off point (fig. 4).

Speed of the flight was 3 m/s , flying over a path was performed with Gimbal Control set for each Waypoint (–90° and –15°). Angle perpendicular to the ground allow creation of the orthoimages, while –15° was chosen during the test flights as an optimal angle for documenting vast area of the landscape. Also 0° and 30° were tested but didn't provide satisfying proportion of sky/land within the allowed range of flight height.

During test flights we saw that automatic Aircraft Yaw following the flight path influences smoothness of the footage, so we decided to change into manual control.

During processing phase image files saved as jpg were added to Agisoft Metashape Photoscan Professional Edition (version 1.7.2). Processing allowed obtaining sparse point cloud (375 366 tie points), dense point cloud (106 924 254 points) and mesh (11 383 080 faces).

Videos were processed Adobe Premiere Pro (Version 23.0) to obtain long shots from shorter videos, which length depend on the visibility of the UAV and

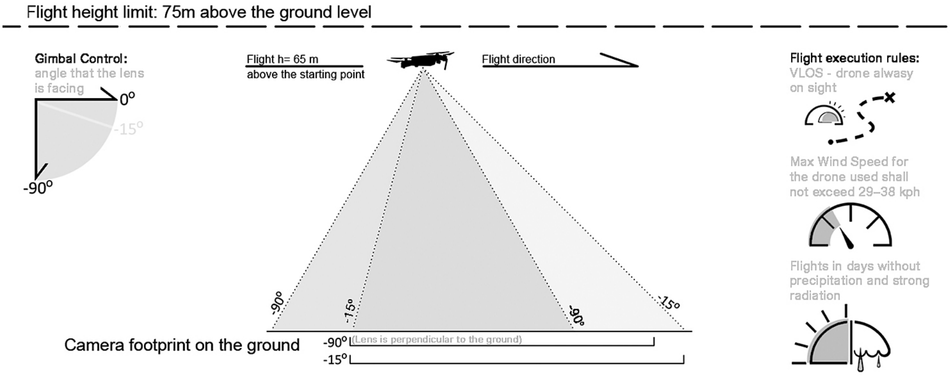

Fig. 4. Flight details: recommended gimbal setups and flight rules

flight conditions. Photographic mosaics for 360° photographs were made in Adobe Photoshop (Version 24.0.1) for online communication of research, to show how perception of the landscape changes if the point of observation changes from human to UAV perspective.

Results

Rediscovered continuity of landscape elements seen thanks by drone video documentation

Videography done with UAVs gives the opportunity to represent a visually continuous experience, with a rich variety of nuances (i.e., depending on time of the day, weather, light, season, activity of humans and fauna, and changes in nature). This is impossible from the ground perspective because of existing obstacles (as infrastructure elements, extensive vegetation, traffic and national roads without pedestrian access to pass). Without flying the UAV it is impossible to follow the river's course, since the area is partially inaccessible. The continuity on the ground level is not possible to be perceived due to river's fragmentation. Changed altitude and video footage angles, allowing focus on diverse qualities of the landscape, is not possible from the human perspective recordings, especially while continuity of natural and urban elements was disturbed: flying we can follow the historical traces, still visible from above the ground, while impossible to perceive from the human eye view. Here, the example can be influence of landscape forms and Torto river's course over historical built environment (as placement of heritage nuclei of S. Frutuoso), which from the ground is nonreadable because of urban sprawl and visual dominance of new multifamily housing.

UAV allows us to change the ways landscape is seen, by emphasizing the river's disrupted continuity where its artificially regulated or placed underground: this type of visual, strong materials can be especially useful to accent human influence on environment, discussed right now due to climate changes and problems Portuguese cities are facing (as flash floods of Porto and Lisbon in winter 2022/2023). Through UAV documentation lack of comprehensive landscape planning in the area of Torto river is especially visible by discrepancy of its course: which in 1 km distance changes from uncared, earth-sided and not regulated (although widely used as a recreation area) to regulated with concrete riverbed and partially hidden underground. This contrast is not striking from the ground perspective, since the area is partially inaccessible: either due to natural and man-made obstacles or to negligence, making the riversides further from S. Frutuoso not as commonly used. UAV footage emphasizes that there is still possibility to revive the continuity of Torto river, making it an important zone for protecting heritage relationships and giving access to nature and high-quality recreation area for the habitants of its rapidly growing neighbourhoods. Thanks to UAV use it is visible, that there is still possibility to maintain visual and territorial unity of nuclei of Dume with nuclei of S. Frutuoso, if the further urban development is planned with consideration of this heritage.

Additionally, documenting landscape in motion, in opposition to static methods, allows dynamic perception of the researched area, focusing on multiple aspects of the space: just as human pinned to one point of focus, but seeing a whole perspective of the area that is being experienced. The perception of the landscape changes thanks to the way it is documented, and ways it can be watched afterwards: through 3D models and videos, also with a possibility of using wearable technology that can make a spectator experience the landscape in ways not possible with traditional, still, 2D documentation techniques. Videogrammetry allows obtaining data for various uses in one flight only: videos can be shown in motion, but also can get processed for obtaining point clouds or 3D meshes.

Information gathered while using various angles of filming, and their influence on understanding the landscape

Methodological approach to the analysis of the graphical outputs included comparison of parameters of data gathered. The gimbal of a drone is controllable, and in the chosen model the range of tilt is: –90 to 30°. During research various angles were tested, with three final solutions implemented (0°, –15°, –90°) for analysis. Altitude of flights was influenced by open slots in the airports schedule, which allowed frequent flights on lower altitude (75 m) with only two-day exception of 120 m limit altitude. Chosen heights had 10m distance below the limit to increase safety of the operations. Perception of the continuity of landscape elements change with different points of view (fig. 5).

Different tilt of the UAV's gimbal (Table 1) allows perceiving and noting varied data, which should be taken in consideration after stating the needs of documentation. Drone documentation on 3m height with 0° gimbal tilt allows footage close to human perspective but is obstructed by many obstacles sensed – it is advised only if it is possible to plan the flight path precisely, on non crowded, accessible for a drone areas. The 0° tilt on 65m height is characterised by limited

Fig. 5. Comparison of footage made by drone following the same path, with different altitude and tilt of the camera: 3 m altitude with 0o tilt (left top), 65 m altitude and –15° tilt (left bottom), 65 m altitude with –90 tilt (right top), 120 m altitude with –90 tilt (right bottom)

Table 1. Different tilts of a gimbal explored

Height and angle	0°, 3 m altitude	0°, 65 m altitude	–15°, 65 m altitude	–90°, 65 m altitude
Horizon visibility	Constrained (obstacles)	Good visibility of horizon	Good visibility of horizon	No visibility of horizon
Influence of Sunlight	High influence of direct sunlight (on sensors or quality of recording)	High influence of direct sunlight (on sensors or quality of recording)	Medium influence of direct sunlight (on sensors or quality of recording)	Low influence of direct sunlight (on sensors or quality of recording)
Observation characteristics	View close to human sight	Limited visibility of the terrain (high sky to terrain ratio)	Far range of sight	Average range of sight, highly dependent on the height of recording
Obstacles	Many obstacles interrupting fluent flight and recording	Small number of obstacles	Small number of obstacles, obstacles limiting or shading view	Obstacles seen from front and back while drone is passing them (giving more data than other types of analysed angles for creation of photogrammetric models)
Flight path precision	Need of highly precise path of flight to evade obstacles (big number of obstacles)	No need of highly precise path of flight to evade obstacles	No need of highly precise path of flight to evade obstacles	No need of highly precise path of flight to evade obstacles (small number of obstacles)

Field of View (FoV) compared to –15° angle, which was chosen as the most optimal for varied use of captured data. –90° angle (pointing to the ground) is the most popular used with photos in photogrammetry, but it has smaller FoV and so the qualitative analysis of videos is limited.

Table 2. Comparison of flights on different altitudes with –90 degrees tilt of drone's gimbal

Altitude	65 m	110 m
FoV	height 563.22 m, width: 29.71 m	height 953.15 m, width: 50.29 m
Shadowing	High influence	Low influence (covering less percentage of the picture)
Wind and battery drainage	Less wind influencing a drone and lower battery draining	More wind influencing a drone and higher battery draining
Coverage	Longer time to cover the same area with comparable photo overlapping as 110 m AGL	Shorter time to cover the same area with comparable photo overlapping as 65 m AGL
VLOS	Further from a pilot	Closer to a pilot
Flight details	Flights can be performed daily (allowance to fly up to 75 m altitude)	Flights can be performed only on days when the airport is closed (allowance to fly up to 75 m altitude daily, and up to 120 m on chosen days without aircraft and emergency helicopter operations)

Altitude of the flight (Table 2) influences FoV of the research that can be covered with one flight. Operations on higher (110 m) altitude allow more robust collection of data compared to 65 m, although the wind has more influence there, draining the battery faster. In this research data was mainly collected on 65m altitude because of nearby airports requirements.

Drone video footage brings the possibility of dynamic landscape surveying, with emphasis on chosen natural or man-made elements, as the exemplary river Torto. The influential aspects were external elements: autumn and winter in Braga has high precipitation, restricting surveying dates. Time to obtain required permits needs to be considered. In this research access to the site was unlimited, without danger of flying over people in groups. For photogrammetry –90° is the most used angle, also bringing good results in videogrammetry, while –15° of the gimbal tilt was chosen to be the most optimal for showing wholesome perception of landscape and its elements, while staying in the allowed flight altitude of 65 m.

Discussion

Drones, thanks to their growing availability, are allowing widespread documentation and enhancing understanding of the landscape (Kleinschroth et al. 2022). Especially compared to other surveying tools, which are expensive and require special abilities or software (as 3D laser scanners).

Importance of continuity of river valleys – as analysed Torto – in urban ecosystem is proven in wide range of case studies (Bedla, Halecki 2021).

Value of connecting cartographic data and photographic documentation is researched in context of reading landscape elements transformation (Purcar 2019), to reveal patterns and connections. Methods for landscape's value identification and perception of historical structures through e.g. aerial surveying are being developed for cultural landscape protection and as base of landscape studies (Slámová et al. 2013), in the wider spectre of digital humanities (Shu 2019). This exploration was focused on qualitative values of the landscape, seen through drone's lens, which as a commercial, low-cost tool, can bring sufficient data for understanding of the landscape. Its outputs, especially without the use of GPS data, cannot give as precise information as airborne laser scanning, for which exist already detailed good practice manuals (Kokalj, Hesse 2017). LiDAR is used in e.g., archaeological (Crutchley, Crow 2018) and cultural heritage research (Historic England 2017). LiDAR datasets sometimes can be found with free access, growing accessibility to this detailed yet expensive surveys, and those could be merged with photogrammetry obtained through commercial UAVs.

The universality of this methodology is based on similarity of EU requirements (Fox 2022) towards UAV use and the resemblance of different types of commercial UAV's. The high importance of popularising drone use workflows can be seen especially in times of conflict, when good quality data can help in reconstruction and protection of heritage, which can be seen in actions od NGO Pixelated Realities, in digitalising and 3D reconstructing heritage of Ukraine in times of war.

Further development of the research is seen in exploration of strengths and weaknesses of videogrammetry compared to photogrammetry of the same area, and preparation of graphical flight manuals for widespread use. Collected data may have variety of potential uses, not only for 3D modelling or surveying, as shown by Perry et al. (2022) and Stöcker et al. (2021), especially if machine learning algorithms are used for input analysis. Additionally, profound landscape analysis of the area will be developed.

Conclusion

Perceiving landscape elements as continuous, in a broad perspective of dynamic video footage, may lead to equilibrated surveys: accenting not only qualities which can be noted on a cartographic documentation, but also emphasizing human way of seeing surroundings as relationships of forms in space.

By this research we aim to strengthen the potential of the drone observation in the understanding of latent relations between morphological elements in the landscape, that can have an influence on creating criteria or premises for more informed interventions, and are not always evident from the ground. UAVs are seen as an effective, cost-efficient design tool, providing insight into landscape conditions and data gathering in existing research in UK context (Cureton et al.

2022). The research results confirmed assumptions that drone is a robust tool for producing a representation of the landscape that by consistency, clarity and strength is very effective in explaining and exploring the territory, thanks to undisturbed, dynamic perception of surroundings provided by drone videography. The results include outlined guidelines for for landscape documentation with use of commercial, accessible UAVs.

Methods of implementation included flights with video and photo survey on altitudes allowed by local authorities (up to 75 and 120 m). Tested specifications including different flight types (manual and planned missions), camera and gimbal setups, lead to the choice of the most optimal setups, including –15° angle for capturing landscape elements and their relationship, and –90° for photogrammetry and videogrammetry.

Information collected by UAV can be used as a keystone joining different areas, from history and archaeology to architecture and urbanism. Understanding of landscape developed through UAV videography provides an opportunity to rethink or revise municipal plans in the sense of reformulating some landscape or landscape unit issues.

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Dokumentacja dronem składników krajobrazu: odkrywanie na nowo ciągłości rzeki Torto w dystrykcie Braga w Portugalii

Zarys treści: Niniejszy artykuł dowodzi słuszności koncepcji wykorzystywania bezzałogowego statku powietrznego (UAV) jako narzędzia badawczego w planowaniu krajobrazu. Pozyskane dane mogą być zastosowane również w archeologii, badaniach krajobrazu kulturowego i dziedzictwa w celu stworzenia wielowymiarowego podejścia do zrozumienia relacji pomiędzy cennymi elementami i zachowania podstawowych cech krajobrazu. Przeprowadzono ocenę, czy UAV jest odpowiedni jako narzędzie badawcze (przez dostępność sprzętu, oprogramowania i metodyki pracy) zdolne do dostarczenia zróżnicowanych ujęć krajobrazu, które mogłyby być wykorzystane w podejmowaniu decyzji planistycznych. Jako przykład zbadano Torto, rzekę w Bradze w Portugalii, od jej przecięcia z rzymską drogą Via XIX. Badania mają na celu pokazanie, że dokumentacja dronem może prowadzić do zwiększenia świadomości na temat zanikającej ciągłości elementów krajobrazu oraz wartości istniejących relacji przestrzennych, które nie są brane pod uwagę w procesach urbanizacji takich miejsc, jak obszar sąsiadujący z ośrodkami S. Frutuoso i Dume, w pobliżu popularnego szlaku pielgrzymkowego Camino de Santiago.

Możliwość identyfikacji i refleksji nad elementami zapewniającymi spójność krajobrazu jest odnotowywana za pomocą wideografii rejestrowanej w trybie *visual line of sight* (VLOS). Przeanalizowano również różne warunki, które należy wziąć pod uwagę, przygotowując się do badań i rejestrując informacje (np. lokalne przepisy, warunki pogodowe, oczekiwane rezultaty), oraz zaproponowano metodologię planowania i wykonywania lotów z najbardziej optymalnymi ustawieniami, z których wybrane zostały: kąt –15° dla uchwycenia elementów krajobrazu i ich relacji oraz –90° dla fotogrametrii i wideogrametrii (tu uchwyconych na maksymalnych wysokościach dopuszczalnych dla obszaru badań, nieprzekraczających granicy 75 i 120 m).

Słowa kluczowe: fotogrametria UAV, wideogrametria, krajobraz, Braga, dokumentacja