Excavations, Surveys and Heritage Management in Victoria

Volume 7

2018

Major Sponsors

Sponsors

Supporters

Contents

The sky's the limit: Applying drone technology to improve cultural heritage management outputs and outcomes, incorporating an example from Bunurong Country

Rebekah Kurpiel[12], Robert Ogden[3] and Daniel Turnbull[3]

Abstract

Drone technology provides a relatively quick and inexpensive method for capturing images and other data from the sky. With the help of dedicated software, the information captured with a drone can be applied to produce a range of outputs with the potential to contribute to the identification, study and management of cultural heritage. This paper presents an overview of some of the approaches that can be employed and presents an example from some research currently underway on Bunurong Country in southeastern Australia. As part of a cultural heritage management project, a 3D model of part of an inland dune system has been produced prior to the landscape being modified for agricultural development. Creating digital archives of this nature allows community members and researchers access to more detailed information about the context in which cultural heritage has been identified than would otherwise be possible. This is a particularly important outcome when the landscape itself is unable to be preserved.

Introduction

Pilotless aircraft technology was originally developed for use in military combat and reconnaissance around the time of World War I, and the term 'drone' was coined by the head of the US Naval Research Laboratory Radio Division in 1936 (Callahan 2014). More recently, drones (also known as Unmanned Aerial Vehicles, or UAVs) have become commercially available, and are commonly used in border and coastal patrol missions (Cook 2007:6), precision agriculture (Stehr 2015), spatial ecology (Anderson and Gaston 2013), environmental conservation and monitoring (e.g. Capolupo et al. 2015), infrastructure maintenance (e.g. Rossi et al. 2014), epidemiology (Fornace et al. 2014), photography (Germen 2016), cinematography (Newcome 2014:2) and competitive racing (Jung et al. 2018:146).

Commercially available drones typically fall into one of four categories: multi-rotor, single-rotor, fixed-wing or hybrid (**Table 1**). Multi-rotor drones use more than one rotor (usually four, six or eight) to fly in all directions, including straight up and down, and to maintain a stable position while hovering. The capacity to hover allows on-board cameras to hold steady, which makes this design ideal for photography and videography applications. Single-rotor drones are also available, and although these are less stable and require a higher level of pilot skill, they typically have higher payload capacity. Single-rotor drones are therefore ideal for applications that require relatively heavy equipment to capture data (e.g. Light Detection and Ranging, or LiDAR). Fixed-wing drones are capable of longer flight times and can therefore range further to collect data from larger areas of land, but are not able to move straight up and down, or backwards, and require a relatively large area to land. Fixed-wing drones are also more likely to be attacked by birds of prey (personal observation). The hybrid vertical take-off and landing (VTOL) design combines the most advantageous characteristics of fixed wing designs (i.e. long range/long flight time) with those of rotor designs (i.e. vertical take-off/landing and hovering capabilities).

Drones in cultural heritage management

In cultural heritage management, drones can be employed to improve outcomes for reconnaissance, recording and data presentation primarily because they allow a range of data to be acquired quickly, usually without increasing the field time required. The data captured using drones can be used to create a range of 2-dimensional (2D) and 3-dimensional (3D) outputs, which are described below. Some outputs can be viewed in real time, providing new information immediately and facilitating on-the-ground decision making during fieldwork.

2-dimensional outputs

2D images captured from drones can provide context for cultural features and landscapes (e.g. oblique perspective shots). Images captured from directly above can be developed into high-resolution basemaps. Alternative spectral representations (e.g. multi-spectral imaging) can also be used to display information that is not recognisable to the naked eye.

Aerial imagery

Most commercially available drones are equipped with cameras capable of producing high-resolution imagery, even for large subject areas. When a subject

[1] Department of Archaeology and History, La Trobe University Vic. 3086; r.kurpiel@latrobe.edu.au; +61403 165 203

[2] Wild Dog Archaeology, 30 Acacia Street, Hamlyn Heights Vic. 3215

[3] Bunurong Land Council Aboriginal Corporation, PO Box 4128, Frankston Heights Vic. 3199

Design type	Multi-rotor	Single-rotor	Fixed-wing	Hybrid VTOL
Capabilities	Vertical takeoff/ landing, can hover, agile, camera control and stability	Vertical takeoff/ landing, can hover, relatively high payload capacity and long range flights	Longest range and flight times, fast flying	Vertical takeoff/ landing, can hover, long range and flight times
Disadvantages	Short flights only	Expensive, complex, high level of pilot skill required	Cannot hover, takeoff/landing requires space, moderate level of pilot skill required	Developing technology, expensive
Best applications	Short range, stable aerial photography/ videography	LiDAR, other applications that require relatively heavy equipment	Aerial mapping/long range inspection	Long range payload delivery
Battery life/alternatives	Relatively short, battery only	Relatively long/can also run on petrol	Relatively long/can also run on petrol	Relatively long/can also run on petrol

Table 1: Characteristics of different drone designs

is photographed from a substantial distance (e.g. from the sky) it is desirable to use a camera with a relatively large image sensor that captures a high number of pixels so that fine details in the image can be seen clearly. Multiple aerial photographs can be stitched together using dedicated software to create orthophotographs, or geometrically corrected images, of larger areas of land. Orthophotographs have the same lack of distortion as a map, and can therefore be georeferenced and used in the same way as maps (e.g. to derive measurements between features).

These outputs can also be generated using manned aerial vehicles, such as aeroplanes and helicopters, but drones are typically a more cost-effective option. Most commercially available drones also facilitate real-time viewing from the ground (on a smartphone or tablet). In the context of cultural heritage management, real-time viewing enables immediate decisions to be made in the field based on current information. For example, archaeological surveys that cannot include the entirety of a large study area can be designed to target areas with good ground surface visibility once these areas have been identified using a drone. An 'eye in the sky' can provide up-to-date information about conditions more quickly and thoroughly than reconnaissance undertaken from a vehicle, including information derived from difficult-to-access parts of a study area.

Multi-spectral imaging

Multi-spectral imaging devices capture image data within specific wavelength ranges, and these are commonly used to assess vegetation coverage and health, including the health of crops (Candiago et al. 2015). Since crop health can be influenced by the characteristics of subsurface deposits, multi-spectral imaging devices have the potential to be used for archaeological prospection in crop paddocks (Webber et al. 2017). For example, crop health is likely to be reduced if subsurface features are limiting root penetration (e.g. if structural features or foundations are present). Conversely, crop health is likely to be improved if previous disturbance has resulted in less compact sediments, which facilitates root growth (e.g. if previous 'cut and fill' activities have been undertaken). Subsequently, any irregularities identified in crop health can be examined for patterns revealing subsurface archaeological features, such as stone wall and building foundations, or previous earthwork activities (Webber et al. 2017). This approach to archaeological prospection can be quicker and easier than geophysical prospection techniques, such as magnetic gradiometry, but it can only be applied to study areas characterised by uniform vegetation profiles, such as crop paddocks.

3-dimensional outputs

3D models of features and landscapes can be produced using data collected from drones, allowing the subject to be viewed digitally in 3D from any angle. The models typically exhibit a high degree of accuracy, and can be used to measure and define attributes, and to facilitate information sharing and preservation. For example, trees from which bark has been removed (culturally scarred trees) can be recorded in 3D, and attributes such as scar dimensions can be measured digitally. Landscape models can be used to define landforms that may be relevant to archaeological investigation, and to display and preserve 3D landscape information—even after development has occurred (see the example from Bunurong Country described below). 3D landscape models can and have been produced manually, for example by recording the height of the ground surface at numerous points using a total station, but drones can capture the same data in a fraction of the time.

Digital image matching

Digital image matching is a photogrammetric approach that uses multiple, overlapping photos captured from known positions in a series of rows to produce a 3D point cloud. The position of each point is determined using algorithms that calculate the 3D location of a point based on the intersection of notional lines from the centre of the camera through to that point,

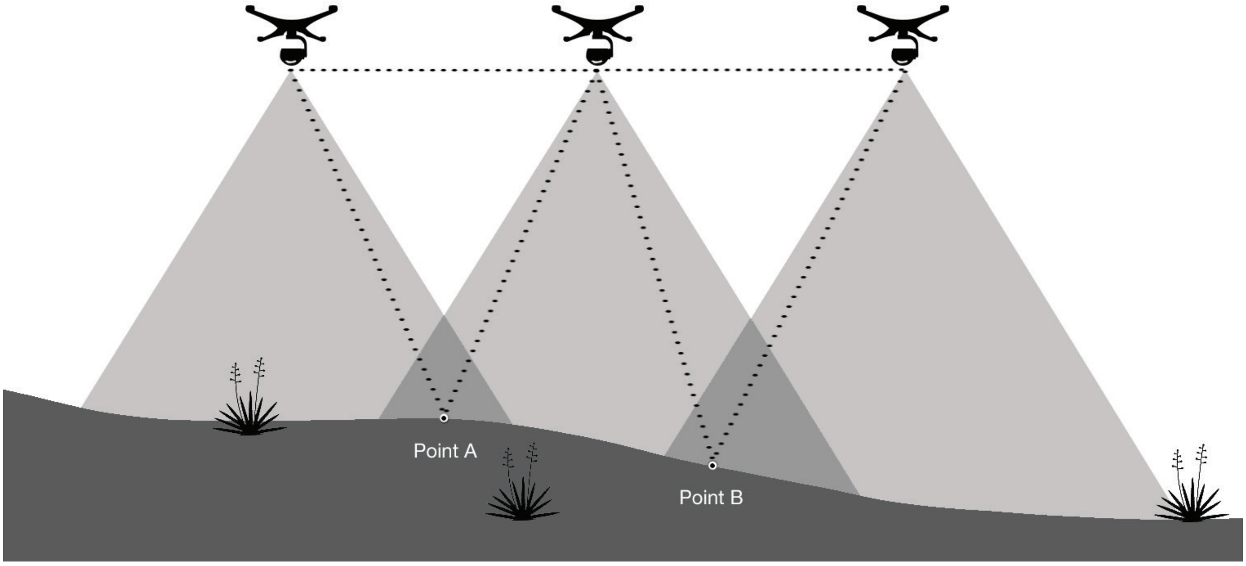

Figure 1: Digital image matching determines the 3D location of points based on the position of that point in two images taken from different positions. Many thousands of points are calculated by digital image matching software in order to produce a detailed 3D model

from two different angles (i.e. from the position of the camera in two different photos that show the same point) (**Figure 1**). This method was used to produce the 3D model presented in the example from Bunurong Country described below.

Airborne laser scanning

Airborne laser scanning techniques, such as Light Detection and Ranging (LiDAR), can also be implemented using drone technology to generate 3D landscape models. LiDAR determines the 3D location of a point by illuminating the target surface with rapidly pulsed laser light and measuring the reflected pulses with a sensor to directly measure the distance. One major advantage of LiDAR over digital imaging matching is its capacity to provide ground surface models for study areas with moderate to high vegetation density. However, a drone with substantial payload capacity is required to carry LiDAR equipment, and these tend to be relatively expensive (**Table 1**). Single-rotor or larger multi-rotor drones (six or eight rotors) are commonly used for airborne laser scanning.

Digital landscape data preservation: An example from Bunurong Country

The case study outlined below demonstrates the use of a drone to collect data to produce a georeferenced 3D landscape model for a study area of approximately 50 acres, situated on the Mornington Peninsula, on Bunurong Country in southeastern Australia (**Figure 2**).

Project background

The study area is located on an inland dune system that is highly sensitive for the presence of Aboriginal cultural heritage. Prior to the commencement of this project, the most detailed elevation map available exhibited 10 m contour lines, which was not sufficient to accurately characterise the landscape. Although the overall gradient is disclosed by the 10 m contour lines (there is a total fall of approximately 30 m from east to west), the study area contains a series of small rises and undulations.

The study area landscape is proposed to be heavily modified by future agricultural development. Archaeological subsurface testing revealed the presence of Aboriginal cultural heritage (see results below). The lack of detailed elevation data, the association between artefact density and landform, and the pending loss of the landscape itself prompted the use a of drone to record the landscape and to create a georeferenced 3D model from the data.

Methods

The images for the preparation of the 3D landscape model were captured using a DJI Phantom 4 Pro drone. Digital image matching was undertaken using AgiSoft PhotoScan Professional (Version 1.4.1) to produce a 3D point cloud and to overlay an orthophotograph to display colour imagery on the model. AgiSoft PhotoScan Professional (Version 1.4.1) was also used to manually classify points in the 3D point cloud. This additional step facilitated the removal of incorrect ground height representations caused by the presence of vegetation around the perimeter of the study area, and resulted in the production of a more accurate 3D landscape model. QGIS (Version 3.2) was used to georeference the 3D model, and to plot the artefact point data.

Results

The 3D landscape model shows the undulating dune landscape of the study area. In the 3D model, the complexity of the topography is evident, with several rises of various sizes and shapes clearly visible (**Figure 2**).

During archaeological test excavation, a total of 124 flaked stone artefacts made on a variety of raw materials were identified at varying depths across the study area, generally at a low density of less than 1 artefact per m^2.

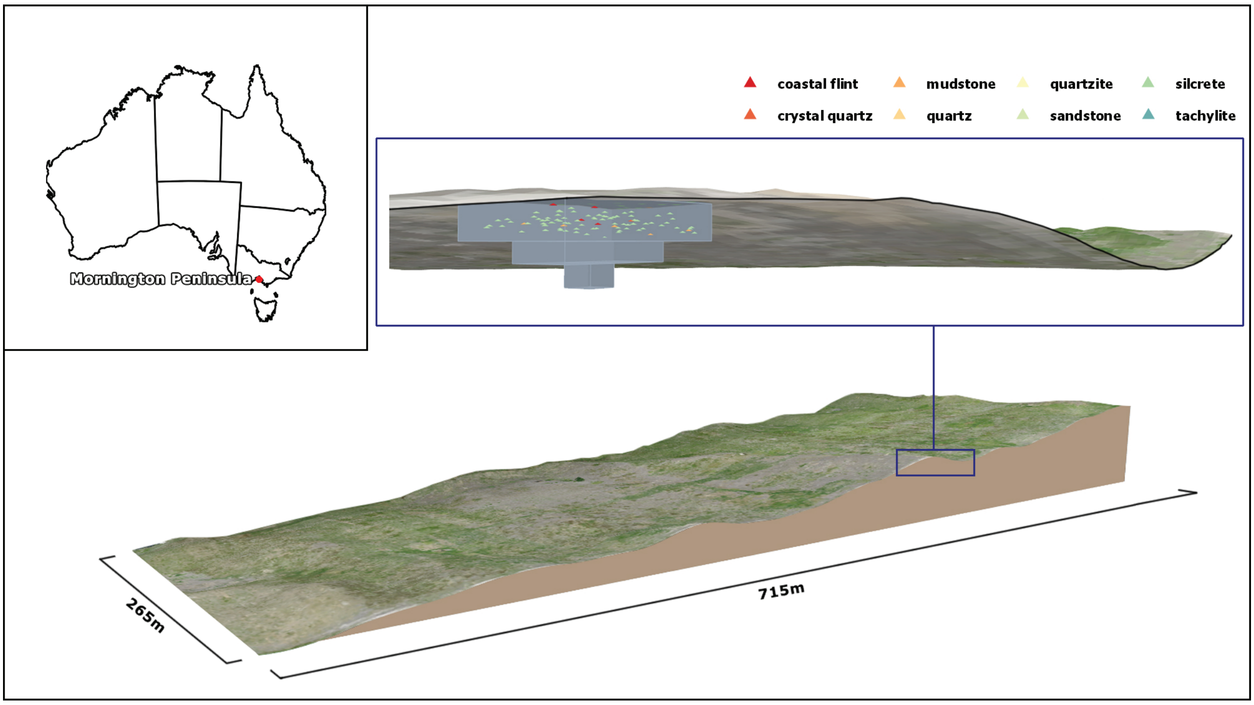

Figure 2: Still image of the 3D landscape model produced using data captured with a drone. Close-up (top right) shows the rise with the highest artefact density with artefact point data and excavation polygon plotted in 3D

The highest artefact density of 3.63 artefacts per m^2 was associated with one of the largest rises. These artefacts, and the stepped excavation polygon, have been plotted into the 3D landscape model so their position can be viewed with reference to their landscape context (**Figure 2**).

Within the 3D landscape model, it is also possible to visualise specific information contained in the dataset. Specifically, point data for individual artefacts can be colour-coded by attribute, allowing the distribution of artefacts with particular characteristics to be visualised and studied. In this example, artefacts made on different raw materials are represented by different colours (**Figure 2**).

The undulating dune landscape of the study area will be heavily modified prior to the proposed agricultural activities. The use of a drone to capture data has facilitated the creation of a 3D landscape model with Bunurong cultural material plotted into it, facilitating further study and allowing access to information about the landform context that would not be available otherwise.

Discussion and conclusion

Drone technology provides a relatively quick and easy way to collect large amounts of detailed and accurate data. A variety of 2D outputs can assist with archaeological prospection, as well as mapping and recording cultural features and landscapes. Georeferenced orthophotographs produced from drone imagery can serve as high-resolution base maps, and perspective shots taken from the sky can provide contextual information. Some archaeological features, including subsurface features, can be identified in drone aerial imagery, especially multispectral imagery, and it is also possible to use information provided in real time to implement targeted survey strategies based on current information.

The capacity to quickly and easily produce 3D models of features and landscapes, including relatively large areas of land, contributes further to the documentation and study of cultural heritage and landscapes. These 3D models can be shared between interested parties and archived for future access by community members and researchers. This is particularly important in the context of cultural heritage management, where development or other proposed activities may result in substantial modifications to cultural landscapes.

Drone technology has the potential to make substantial contributions to cultural heritage management outputs and outcomes, and the capabilities of most commercially available models are well-suited to the dynamic working environments associated with archaeological fieldwork. Research into the specific ways that drones can be used to identify a variety of Aboriginal cultural heritage features is currently underway.

Acknowledgements

Rebekah wishes to acknowledge the Bunurong community, of which her co-authors Rob and Dan are a part, for welcoming her to work on their beautiful Country for a number of projects over the years. Useful discussions about drone technology were had with Paul Penzo-Kajewski, Louisa Roy, Katherine Thomas and Jacqui Tumney, so thanks also to them, for sharing ideas and enthusiasm.

References

Anderson, K. and K.J. Gaston 2013 Lightweight unmanned aerial vehicles will revolutionize spatial ecology. *Frontiers in Ecology and the Environment* 11(3):138–146

Callahan, A.L. 2014 Reinventing the drone, reinventing the Navy: 1919–1939. *Naval War College Review* 67(3): 98–122

Candiago, S., F. Remondino, M. De Giglio, M. Dubbini and M. Gattelli 2015 Evaluating multispectral images and vegetation indices for precision farming applications from UAV images. *Remote Sensing* 7(4):4026–4047

Capolupo, A., S. Pindozzi, C. Okello, N. Fiorentino and L. Boccia 2015 Photogrammetry for environmental monitoring: The use of drones and hydrological models for detection of soil contaminated by copper. *Science of the Total Environment* 514:298–306

Cook, K.L. 2007 The silent force multiplier: The history and role of UAVs in warfare. In *2007 IEEE Aerospace Conference Digest, Big Sky, Montana, March 3–10, 2007, pp.* 1–7. Big Sky: IEEE

Fornace, K.M., C.J. Drakeley, T. William, F. Espino and J. Cox 2014 Mapping infectious disease landscapes: Unmanned aerial vehicles and epidemiology. *Trends in parasitology* 30(11):514–519

Germen, M. 2016 Alternative cityscape visualisation: Drone shooting as a new dimension in urban photography. In J. Bowen, N. Lambert and G. Diprose (eds.), *Electronic Visualisation and the Arts (EVA July 2016)*, pp.150–157. London: BCS

Jung, S., S. Cho, D. Lee, H. Lee and D.H. Shim 2018 A direct visual servoing-based framework for the 2016 IROS Autonomous Drone Racing Challenge. *Journal of Field Robotics* 35(1):146–166

Newcome, L.R. 2004 *Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles*. Virginia, USA: American Institute of Aeronautics and Astronautics

Rossi, M., D. Brunelli, A. Adami, L. Lorenzelli, F. Menna and F. Remondino 2014 Gas-drone: Portable gas sensing system on UAVs for gas leakage localization. In *SENSORS, 2014 IEEE*, pp.1431–1434. Piscataway: IEEE

Stehr, N.J. 2015 Drones: The newest technology for precision agriculture. *Natural Sciences Education* 44(1):89–91

Webber, H., V. Heyd, M. Horton, M. Bell, W. Matthews and A. Chadburn 2017 Precision farming and archaeology. *Archaeological and Anthropological Sciences.* 22/11/17:1–8