Unmanned Aerial Vehicles, applications in stream monitoring and management

James Rennie[1]

1. Australian UAV, PO Box 6106, Cromer, Vic 3193. Email: contact@auav.com.au.

Key Points

- Unmanned aerial vehicles (drones) offer a cost-effective way to collect aerial data
- Photogrammetry can be used for survey design of structures and 2D hydraulic modelling
- 2.5cm/pixel images enable the mapping of pest species, flora and fauna
- Mapping at the management intervention scale provides a tool for conveying progress to investors
- Aerial video documents change in a way that connects with the community

Abstract

The use of Unmanned Aerial Vehicles (UAVs, or commonly known as 'drones') in the management of rivers has opened up a wide range of cost-effective tools for land and waterway managers. Fixed-wing UAVs have been used extensively across Victoria and NSW for high resolution mapping of vegetation, weeds and pest animals. The aerial survey data has proven particularly useful in fluvial geomorphological assessments and erosion mitigation design.

This paper explores the types of data capture available to waterway managers, example applications and pitfalls. With over 50 projects completed across Victoria and NSW that are directly related to waterway and floodplain management we draw upon examples of varying success using current UAV technology.

Aerial survey with LiDAR has become the standard across much of Australia. In 2010 Victoria captured some 26,000km of rivers with a state-wide capture program. Mapping change from this benchmark at the reach scale with LiDAR is cost prohibitive. With the advent of UAVs this data capture is in the hands of the river manager. Photogrammetry techniques enable the delivery of highly accurate three dimensional data and photography that quantifies change at the local scale. The data is also fit for purpose for erosion engineering structural design and two-dimensional modelling of channel hydraulics.

With the ability to capture up to 1000ha per aircraft per day, this transformational technology has a wide application. Cost-effective aerial image capture has also opened up possibilities of post flood & fire mapping and monitoring with response time deployment being hours rather than days or weeks.

Keywords

Drone; photogrammetry; survey; monitoring; evaluation; design; UAV;

Introduction

The advent of the "drone age" in the past three years has seen the widespread uptake of Unmanned Aerial Vehicle (UAV) technology across a range of industries. High-resolution aerial mapping data is not a new technology for river managers, it has been used in planning, monitoring and assessment for decades. However, the scale and budget requirements of the traditional aerial mapping meant that the frequency of aerial capture, and the scale required to become economically viable, leant itself to whole of catchment mapping rather than the management scale.

The increase in the use of UAVs has enabled river managers working on the ground to commission inexpensive aerial images and surveys over small areas and repeat this capture to plan, monitor and demonstrate change.

There are two distinct forms of 'drone' or Unmanned Aerial Vehicle (UAV). The fixed-wing UAV (Figure 1)) used for broad area ortho-mapping and survey, and the multi-rotor UAV (Figure 2), typically used for oblique aerial photos and video.

It is the latter that achieves the media attention, mostly for the wrong reasons, however it is the fixed-wing UAV is the quiet achiever, with some variants able to map over 1000ha per day with 2.5cm ground pixel resolution. This resolution is far better than the traditional aerial 15cm pixel images from manned aircraft, and obtainable for a fraction of the cost at the reach scale.

Figure 1. Fixed wing UAV

Figure 2. Multi-rotor UAV

The applications of this technology in river management are continuing to flourish, a process that is facilitated by the readiness of river management practitioners to adopt new technology. This paper will outline some of the existing applications that have been proven successful and the data that is delivered.

Applications with a Fixed-Wing UAV

As noted above, in ideal conditions a medium sized fixed-wing UAV will capture up to 1000Ha of aerial images with a 2.5cm resolution per day. The aerial images are stitched into a single geo-referenced ortho-mosaic image for use in GIS and can be interpreted in the same way as any traditional aerial image, though with the significant advantage of its much higher resolution (Figure 3 and 4).

Figure 3. Example image from fixed-wing UAV monitoring waterway vegetation

Figure 4. Identification of possible impacts on waterways

The resolution of the data facilitates the mapping of weeds, and the addition of multi-spectral cameras (see below) further enhances the species distribution mapping. Typical horizontal accuracies with regard to MGA coordinates are in the range of 1-2 metres, relative accuracies in most conditions are in the centimetres range. This enables the end user to measure and plan sites, map areas of works and plan actions with confidence. If needed, the global accuracy can be improved up to ~5 cm through the use of a high-end GPS system on board the drone, or ground control targets.

Photogrammetry

A bi-product of the fixed-wing UAV data collection and mapping is the production of a 3D Digital Surface Model (DSM). The model is derived from the stereo pair images thus creating a three dimensional point at each pixel. The density of the points is therefore up to 1500 points per square meter which gives unparalleled data richness. Figure 5 below represents a digital surface model of a river channel and hydraulic floodplain control. The detail of the terrain model even picks out the tyre tracks on the gravel bar and a mobile sand slug progressing down the channel (top left of Figure 5).

As with LiDAR the created point cloud or surface model enables the computation of the heights of vegetation (Figure 6), identification of erosion and analysis of the fluvial geomorphological features. Automated interpretation of this data lends itself to the assessment of vegetation continuity and establishment along a river.

The data is also in a format suitable for one, two or three dimensional hydraulic modelling, monitoring sediment distribution and movement .

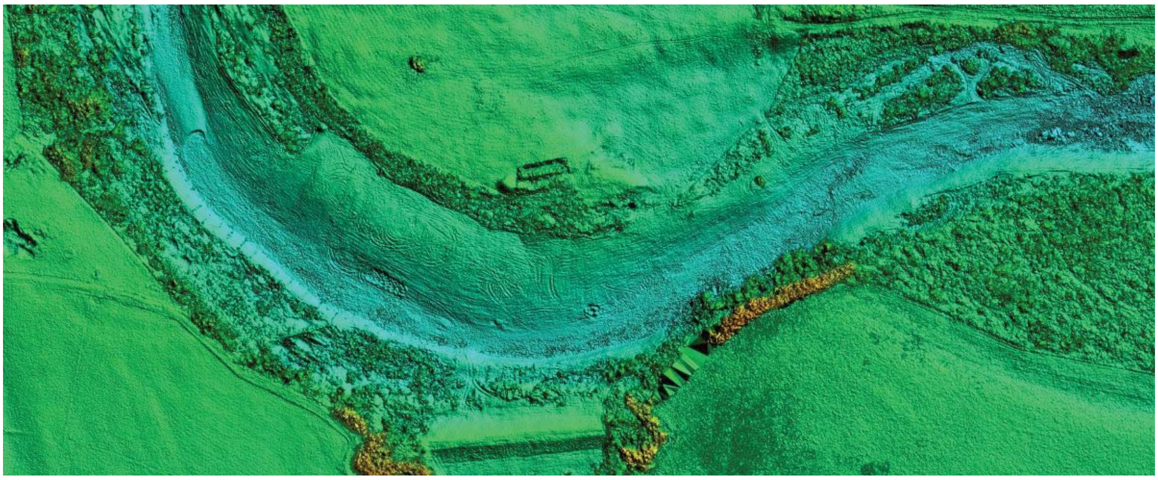

Figure 5. Surface model of river channel

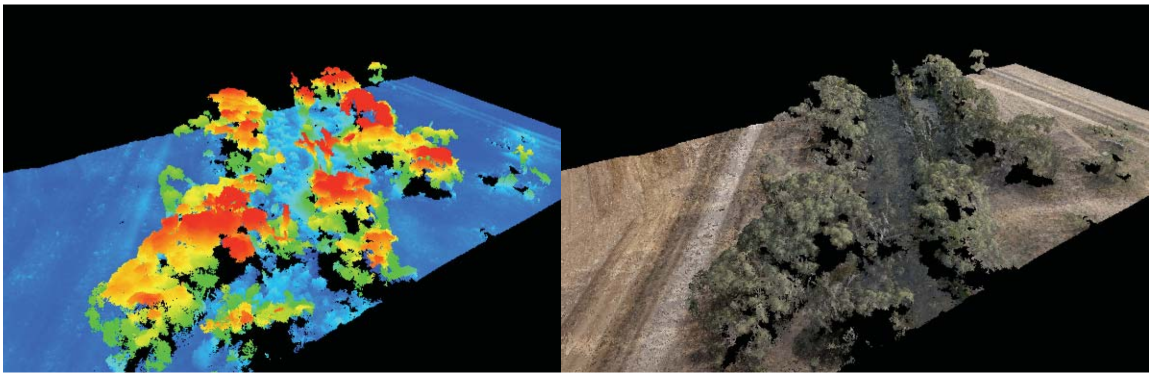

Figure 6. Tree heights and overhang analysis along a waterway with colour point clouds

Carbon Accounting and Vegetation Establishment

Although still in early development, we are working with a number of partners to assess the possibilities of carbon accounting for revegetation projects. The canopy height and volume of vegetation can be derived and therefore suggests the possibility of assessing the carbon sequestered. Watch this space for further developments.

Figure 7. Canopy height models and vegetation cover for carbon accounting

Survey

The accuracy of the digital surface model increases with either the use of an RTK (Real Time Kinematic) GPS equipped UAV or the provision of ground control. With these approaches the accuracy of the point cloud will be approximately 3-9cm in the vertical. With the density of the point survey it far exceeds the fit for purpose quality achieved by aerial LiDAR or a field based survey. With this level of accuracy and point density the survey data is suitable for hydraulic floodplain modelling, erosion progression monitoring and design.

The data accuracy and detail attained by UAVs is suitable for designing intervention works such as rock chutes, pile fields or grade controls. On a larger scale, cliffs (Figure 8) and gullies can be monitored for stability and sediment budget analysis.

Figure 8. Aerial survey point cloud of an actively eroding cliff to monitor movement

Alternative Sensor Technologies

Although the vast majority of our work with small UAVs captures colour imagery using RGB camera sensors, we occasionally have need for alternative sensors as described below.

Thermal

The thermal camera accurately maps the differences in temperature across the landscape. Thermal cameras can be flown to map feral animals and identify leaks in irrigation infrastructure/dams/levees.

Although untested, there are opportunities to efficiently map the temperature of mixing water below large storages to assess the cold water distribution.

Multi-spectral

Multi-spectral cameras enable the interpretation of plant health and species mapping. The characteristic spectral signature of a species can often be isolated and used to interpret an image to identify the location of patches of plants or individuals. This technique has been successfully applied in Victoria to map *Spartina* in salt marshes.

There are also possibilities to map the extents of blue-green algae, a trial will be undertaken in summer 2016/17.

LIDAR?

- Getting smaller/cheaper/lighter, and therefore close to being a good option, particularly for scenarios where you need to survey terrain beneath heavy vegetation canopy

Limitations

There are limitations to the uses of elevation data derived from photogrammetry. Key amongst these is the presence of vegetation if the detail under the canopy is required. The top of vegetation/buildings will be referenced as the ground surface and may require additional work to manually remove and interpolate.

It is not always possible to map all landscapes, for example the mosaic software uses pixel matching and therefore large areas of tall native forest, open water or crops may not be successfully stitched together, due to the lack of distinct visual features to correlate between neighbouring images.

Aside from the technological limitations, there are also regulatory limitations. One consideration is the requirement for UAVs to be flown within the line of sight of the operator, which in turn requires the area being surveyed to have vehicular access and a suitable take-off and landing location nearby. New regulations for Beyond Line Of Sight (BLOS) flight are under development, and this should be feasible in remote areas within a short number of years.

Applications with a Multi-Rotor UAV

Multi-rotor UAVs are suited to the documentation of change. For many years, river management specialists have completed fixed point photo monitoring from the ground. In respect to the re-vegetation of riparian areas there are limitations with this approach, for example, when the vegetation becomes established you cannot see the wood for the trees.

Gaining an elevated view provides a far better overview of the works area and conveys a clearer message of change. The provision of an aerial video extends that that one step further with flights along the same GPS flight paths playing side by side clearly articulating the change achieved through the undertaking of the works. This has been employed successfully by a range of government NRM organisations in Victoria and NSW.

Figure 9. Monitoring waterway change before willow removal works

Figure 10. Pre and post environmental watering in western NSW

Multi-rotor UAVs can also be used to map small areas, but are compromised by their short flight times. At best a multi-rotor will achieve a mapped area of 5-15ha per a flight while a small fixed-wing can typically achieve 50-250ha per flight at the same resolution due to the increased efficiency.

Risks

The risk of UAV loss to wildlife is a factor that only manifests itself significantly in Australia. The Wedge Tailed Eagle is the natural predator of the UAV. With an average attack rate of one flight in 5 and the consequential loss of UAVs, the threat cannot be understated.

With reports of some operators losing up to four UAVs in 12 months at a cost of $20,000-40,000 each the financial ramifications are considerable. The risks can be minimized through experience, flight planning and UAV choice, however the likelihood of loss in the first year of operation would be upwards of 50% for anyone operating outside of a metropolitan area.

Figure 11. Birds of prey pose a significant risk to UAVs

Conclusions

UAV technology complements the existing use of manned aerial imagery, LiDAR and field based survey techniques. It presents a cost-effective method of mapping, monitoring and evaluating river management works at the reach scale as well as mapping for prioritisation more broadly.

Over the past three years we have seen the use of UAV technology transition from novelty and trial to mainstream management, built into the planning, monitoring and evaluation of river management projects.

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