THE USE OF A UAV AS A REMOTE SENSING PLATFORM IN AGRICULTURE

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ABSTRACT

One of the limitations of using hobbyist remotely controlled aircraft with an attached digital camera is that a great number of images look alike and unless a large number of natural features or artificial targets are present at the location, it was hard to identify and orientate the images.

This paper investigates the use of an unmanned aerial vehicle (UAV) for use in agricultural applications. Trials were conducted, in collaboration with researchers from the Australian Research Centre for Aerospace Automation (ARCAA) - Queensland University of Technology (QUT), on the ability of the UAV autopilot to accurately trigger the 2-camera sensor when at a desired location.

The study area was located at Watts Bridge Memorial Airfield, near Toogoolawah (152.460º, -27.098º) in South East Queensland, Australia. The airfield has dedicated areas for use of remotely controlled aircraft, with the mission being undertaken on 5 March 2008.

The target and waypoints were arranged so that the UAV flew in an anti-clockwise flight pattern. Three separate missions were flown with images being acquired when over target on each of the nine passes. Although capturing the target in the image was achieved on every flight, the accuracy of capturing the target in the middle of the image was variable. The offset from the centre of the image to the target (zero in the perfect system) ranged from just under 15 to just over 60 % of the image extent. The misalignment was due to a combination of cross-wind, GPS / autopilot error, the UAV not being level when the image was acquired, and / or inaccuracies in positioning the sensors in the hinged pod.

The capacity to accurately acquire images over pre-determined points is essential to ensure coverage and to expedite mosaicing of the images. It will also expand the application of these technologies into the broader-scale applications, such as imaging in broadacre cereal cropping or imaging along transects.

Keywords: autopilot, UAV, remote sensing, digital cameras, autonomous
INTRODUCTION

The use of unmanned aerial vehicles (UAV) as a remote sensing tool is not new, with a number of recent studies detailing various applications: off-the-shelf componentry was used to construct a UAV for rangeland photography (Hardin & Jackson 2005), a camera equipped UAV was used for wilderness search and rescue (Goodrich et al. 2008), a very expensive and sophisticated UAV (the NASA developed Pathfinder) was used for coffee ripeness monitoring (Johnson et al. 2004), and UAV were used to monitor wheat in small plots with colour and NIR images acquired to develop relationships between vegetation indices and field measured parameters (Lelong et al. 2008).

The above remote sensing method either used real-time monitoring of the acquired imagery, or required a large number of images to be taken and the most appropriate being selected for future analysis. No previous studies have investigated the capacity of using a UAV to only acquire an image when at a particular location (or set of co-ordinates). The ability of a UAV to track to a particular set of co-ordinates was however detailed in a paper investigation spore collection from the air (Schmale III et al. 2008). These investigators utilised the GPS trace to determine the flight path of the UAV.

The purpose of this investigation was to evaluate the fully autonomous image acquisition system. To achieve this objective, the ability of the autopilot to trigger the remote sensing camera system was tested, and the accuracy of the autopilot (in an x y z direction) was also evaluated. The procedures to perform this testing and evaluation are detailed in this paper.

Study area

The study area was located at Watts Bridge Memorial Airfield, near Toogoolawah in South East Queensland, (152.460°, -27.098°), Australia (see Figure 1). The mission was undertaken on 5 March 2008.

![Figure 1 Location of the Watts Bridge Memorial Airfield.](image)

Platform

To undertake this evaluation, a specially modified version of a “Phoenix Boomerang” 60 Size Trainer was utilised (details at [http://www.modelsports.com.au/](http://www.modelsports.com.au/)). The platform consisted of two 60 size Boomerangs merged together. The platform (shown in Figure 2) was powered by an “OS
Engines” 91FX (16 cc) (details at http://www.osengines.com/) methanol-glow motor. The baseline avionics on the platform included the “MicroPilot MP2028g” autopilot (details at http://www.micropilot.com/) and a “microhard Systems Inc. Spectra 910A” 900 MHz spread spectrum modem (details at http://microhardcorp.com) for communications with the ground control station.

![Figure 2 The QUT UAV ready for take-off.](image)

**The remote sensing system**

The remote sensing system used to acquire images was based on the system developed and detailed in Jensen (2007). This investigation utilised 5.0 megapixel Kodak Easyshare CX7525 (specifications available from www.kodak.com) Digital Zoom Camera (Eastman Kodak Company, Rochester NY). As described in the previous work, the 2-camera system (one camera to capture the colour and the other the near-infrared portion of the spectrum) was remotely triggered, and were sensitivity to near-infrared light (once the NIR cut-out filter had been removed).

The system was housed in a streamlined pod attached to the underside of the fuselage directly beneath the wing. The pod was hinged for easy access and download of the cameras (see Figure 3). As the sensor had been previously triggered using a spare output channel of the radio control equipment, this was easily adapted to suit the autopilot system. When the UAV was within a certain distance of the designated location (within a 20 m radius to allow for cross-winds, GPS error and misalignment) the autopilot set a spare servo channel to the maximum output for 600 ms. A micro-controller (PICAXE-08, details at http://www.picaxe.co.uk) was programmed to monitor the pulse width on the designated channel of the radio equipment and this used to trigger both cameras. The microprocessor also gave both cameras a pulse every 10 s to ensure that they did not power down.

**Deployment**

The UAV was programmed with a flight plan instructing it to do a number of left circuits over a series of pre-determined waypoints (see the Horizon Flight Schedule software in Figure 4). The waypoints are shown as pink dots in this image. One of the dots is green, indicating that this is the next waypoint that the UAV is heading towards. When passing above the origin point (the target of the image acquisition and where the UAV was initialised), the autopilot triggered the cameras.
The pod opened to remove the SD cards from the sensors.

The takeoff of the UAV was performed manually. Upon reaching a safe altitude (30 m – 100 ft), the UAV was switched into autonomous mode and the autopilot started guiding the aircraft along the set track, with flight height targeted at 120 m above ground level (AGL). When the UAV approached the imaging target (the initialisation point) the UAV was instructed to change altitude to 90 m AGL. The change in altitude was performed so that most of the flight was at a higher (hence perceived safer) altitude and likewise to simulate flying over obstructions and coming down
to image acquisition height. Once past the target, the UAV resumed normal flying height. After 15–20 minutes of autonomous flying, the UAV was manually landed and the flight log was downloaded from the autopilot.

The log contained 52 columns of information, recorded at 5 Hz, about the aircraft’s state that includes the following attributes: attitude, position, speed, heading, servo values, etc. Four flights were undertaken on the day of testing with images successfully captured on three of these. The second flight had to be aborted and the UAV landed immediately, as conventional aircraft came into the proximity of the UAV. The imagery acquired was analysed to provide flight path accuracies.

RESULTS AND DISCUSSION

A flight path of the three successful missions is shown in Figure 5. Two circuits were completed on both flights one and three, with three circuits being made on flight four. Each dot in the circuit represents the latitude and longitude of the path taken by the UAV that was recorded in the flight log, which was updated with GPS co-ordinates once per second. The activity around the target area and the reduced distance between consecutive dots in this area indicates that this was the takeoff and landing zone. The flight path is superimposed over a Spot 5 satellite image showing the infrastructure of the Watts Bridge Memorial Airfield and other natural features in the close proximity. Also displayed are the waypoints used in determining the flight path and the location of the target, over which the images were captured.

![Figure 5 The flight paths and target positioning, Watts Bridge on 5 March 2008.](image)

An example of two of the images captured on flight four are shown in Figure 6. These images were taken on the last circuits made by the UAV on the day. Even though the images were acquired a little over three minutes apart, there is good consistency in the coverage and positioning of the target within both images. Ideally, if the autopilot was doing a perfect job guiding the UAV, the target should be in the centre of the image. As can be seen from the images (Figures 6), this was not quite the case.
The target and waypoints were arranged so that the UAV should in theory fly directly down the centre of the mowed grass runway that ran NE–SW in Figure 5. This should have resulted in the runway being positioned vertically in the centre of each image acquired. This was not the case. The misalignment was possibly due to a combination of cross-wind, GPS / autopilot error, the UAV not being level when the image was acquired, and / or inaccuracies in positioning the sensors in the hinged pod. Defining the errors and refining them was not part of this proof-of-concept.

Details of the various images captured during the flights undertaken are shown in Table 1. The inaccuracies in the image acquisition were quantified and detailed in this table. The scale of the image was determined using GPS co-ordinates of known features and the distance measured from the images. The direction of flight of the UAV was from the top of the image to the bottom. In the image offset column in Table 1, the X distance is the cross-track distance with a positive value indicating that it is to the left and negative to the right of the centre of the image. The offset in the direction of flight (undershoot or overshoot) is indicated by the Y column with a positive value indicating that the image was captured before the centre of the image with a negative value indicating after capture. The absolute is the direct distance from the centre of the image to the centre of the target.

<table>
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<tr>
<th>Image #</th>
<th>Time</th>
<th>Altitude (m)</th>
<th>Heading (degrees)</th>
<th>Image Offset</th>
<th>Image Extent</th>
<th>Area (ha)</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>X (m)</td>
<td>Y (m)</td>
<td>absolute X (m)</td>
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Table 1 Details of the errors for the images acquired over the target.
Capturing the target in the image was achieved on every flight. However, capturing the target in the middle of the image was not as repeatable with the error ranging from just under 15% of the image width (the final image on flight four) to just over 60% of the image width (the second image of flight two).

The capacity to accurately acquire images over pre-determined points is essential to ensure coverage and to expedite mosaicing of the images. It will also expand the application of these technologies into the broader-scale applications, such as imaging in broadacre cereal cropping or imaging along transects (such as river systems etc.).

Also detailed in Table 1 are the differing altitudes that were programmed for each of the flight. The first flight was undertaken at 150 m above ground level, with the third at 110 m. The final flight was slightly different. The first image was acquired at the set altitude of 120 m. The three circuits that followed were flown at this same height (120m); however the images were acquired at lower altitudes (100 m for images two and three and 75 m for the final image). These image acquisition heights were changed in-flight with the intention of observing the response of the UAV to changes of the flight schedule. An altitude plot of flight 4 is shown in Figure 7.

![Altitude plot of flight 4](image)

**Figure 7** Altitude details for flight 4 (note the UAV reduced altitude to acquire images).

Figure 7 shows the relatively steep climb of the UAV after take-off. Also evident is the loss of altitude, and then correction, due to the banking of the aircraft when manoeuvring to align to the next waypoint. The saw-toothed nature of the plot, due to the banking, indicates that the feedback loops to the autopilot to control the flight surfaces are not finely tuned enough to optimise performance and ensure stable flight.

**CONCLUSIONS**

This study provides proof-of-concept that a low-cost autopiloted UAV can fly on a predetermined path and acquire images at predetermined locations. On every attempt, the target was successfully captured in the images. The accuracy of how close the target was to the centre of the image varied due to a number of factors such as windspeed, direction, aircraft attitude and GPS/autopilot/camera lags. The refining of the accuracy of the image acquisition was beyond the scope of this investigation.
This autonomous system has the potential to be a highly suitable platform for ‘real world’ applications, but needs further development to overcome the accuracy issues. As the capacity to perform automatic registering and mosaicing of the acquired images filters down from conventional aerial imagery, this low cost remote sensing system will have great potential to be utilised in broader agricultural applications.

REFERENCES


