Resources

Koala Survey - UAV

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Forest & Wood Products Australia

Koala Survey - UAV

Prepared for

Forest & Wood Products Australia

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Table of Contents

Figures

EXECUTIVE SUMMARY

Kingfisher was contracted by Forest and Wood Products Australia (FWPA) to conduct Koala location trials using Unmanned Aerial Vehicles (UAVs) and Flir infrared equipment. Five trials using various settings, heights and image overlaps were conducted over several months in the Bessiebelle forest area in western Victoria. The data was then sent to the Australian Centre for Field Robotics (ACFR) for processing and for development of an algorithm that would allow computer identification of koala locations. This data would then provide geo reference i.e. X and Y coordinates to forest operators in real time so they could avoid koalas during harvesting.

During the trials, several settings and processes were developed that enabled koalas to be successfully located and the system to be demonstrated. An operational system would include preliminary location of koalas in real time using visual techniques and the Isotherm setting on the Flir camera. Subsequent flights would then be in the grey scale setting with a Teax backpack with onboard processing to allow computer identification and automatic production of geo coordinates for forestry use.

The ACFR computer algorithm was successful in identifying animals although with some false readings. The algorithm is a continuous learning system and will improve over time with continued data collection and use enabling removal of the incorrectly identified animals.

Overall, the infield operations could be conducted by two personnel and each flight would take less than eight minutes covering around 1 hectare, providing a cost effective solution to koala identification prior to harvesting.

The trials were concluded with a successful industry demonstration day where data was collected and koalas identified using the above system.

In addition to the above trial, the Flir camera was tested to see if a suitable ground based system could be developed. Unfortunately, due to the large background heat signature caused by the sky, the ground-based application was ineffective.

In summary, a successful koala identification platform was developed using UAVs and Flir cameras. While further development would be required, operational use of the system could be conducted economically with minimum in field personnel while at the same time improving safety and animal welfare.

The platform can currently be used in the Isotherm setting although the computer system needs refinement with development of on-board processing. This development would be completed quickly and be operational within months of commissioning the next stage of work.

We thank the FWPA for contributing to this project.

1. INTRODUCTION

This project was a 'proof of concept' to locate koalas in commercial eucalypt plantations using UAVs and ground-based platforms fitted with thermal digital imaging cameras and suitable 'koala-identification' software algorithms.

The aerial outputs included locations in latitude and longitude to isolate koala-trees prior to harvest. The ground-based work sought to identify koalas ideally in a tree closest to the observer.

Digital imaging systems mounted on UAVs, drones or ground-based have become more cost-effective and sophisticated. The systems include a wide range of cameras and mounting devices along with increased computing power to analyse images taken. This technology, in combination with ecological knowledge and computer vision algorithms developed by ACFR, offers a tangible alternative to manual (human) ground-based assessments.

1.1 OBJECTIVE

The study objectives were to:

- Improve speed and accuracy in locating koalas in advance of harvesting.
- Deliver a system based on UAVs that provides considerable savings to the industry, ranging from decreased staff and equipment costs to improved accuracy in population counts.
- Provide precision in locating koalas.
- Provide access to terrain that would be otherwise dangerous or difficult on foot and reduce the associated safety concerns when traversing these areas.

1.2 APPROACH

The trials involving UAV equipment were carried out with licensed and experienced pilots, and within the envelope of normal small UAV operations. This meant no specific or formal involvement with the Civil Aviation Safety Authority (CASA) was required.

Figure 1: Licenced and experienced UAV pilots

A suitable and safe site for the trials was selected near Bessiebelle in Victoria. The location is shown in Figure 2.

Figure 2: Trial site at Bessiebelle, Victoria

The trials included the following key steps:

- Selection of flight mission at Bessiebelle to evaluate optimal imaging settings for the identification of koalas.
- Manual ground-truthing by the Kingfisher team to ensure koalas were on-site.

- Selection of a lightweight thermal sensor and a multi-spectral camera suitable for Kingfisher's UAV-mounted on a suitable gimbal.
- Ground-based trial of the thermal camera to mimic a camera mounted on a harvesting machine
- Post processing of captured data.
- Refinement of a detection algorithm with each trial.
- Production of FWPA milestone reports with findings and recommendations.
- Final trial with forest industry contributors to the project.
- Final report (this report).

1.3 THE TEAM

The team consisted of the following:

- Rod Meynink – Forestry Expert and Project Leader
- Trevor Bourne – Project Manager
- Stan Thomson – Technical Director
- Mitchell Bourne – Software and project assistant
- VUAS – Drone Expert
- AFCR – Computer Learning Expert
- Imagus – Shape recognition Expert

1.4 EQUIPMENT

The following is a list of equipment used for the trials:

- FLIR Tau camera
- Teax Data Back Pack – Used from trial 1b
- Drone – Ardupilot based Hexacopter, 680mm frame, 4500grams total weight, 2 axis gimbal
- Safety Equipment
- Red Edge Camera (Fitted but not used)
- Drone Experts Gimbal
- VUAS Gimbal
- RGB Camera

Some of this equipment is shown in the following images.

Figure 3: Equipment used in trials

2. METHODOLOGY

The following were the planned trial stages:

Stage 1 – Pre-trial Systems Development

The platform brought together for the first time multi-rotor UAVs, different cameras (FLIR Tau-2 – a thermal imaging camera utilised in different format and a MicaSense RedEdge multi-spectral camera) along with data processing software. The platform was trialled in the air and on the ground in a plantation environment. There was not any planned industry audience for stage 1 and 2.

The Stage 1 steps included:

- Locate a small number of forest compartments reasonably close to being harvested.
- Obtain necessary trials approval(s).
- Test fly missions on-site to refine UAV/camera setups and procedures focusing on altitude, focal length, survey procedure (grid, start-stop, multi-pass, fixed vs multi-rotor etc.) and communications.
- Test ground platforms for operations.
- Further develop koala-location algorithms for the eucalypt plantation environment.
- Data processing at ACFR.
- Define a trial system covering UAV platform, ground platforms, logistics, camera type, focal length, height above the canopy, number of passes etc.
- Brief write-up and report to client-consortium.

Stage 2 – Full scale closed trial

- Systems check trial-flying one day before manual koala count.
- Manual ground-based count and location work (as per current practices).
- UAV capture of data using a multiple systems and procedures.
- Image processing which may be partially on-site and offsite at ACFR and selected third party associates.
- Refinement of algorithms and re-processing as required.
- Reporting focusing on preferred systems.

Stage 3 – Open trial

- Refinement of trial locations based on anticipated/actual harvesting operations.
- Systems check trial-flying one day before manual koala count.
- Manual ground-based count and location work (as per current practices).
- Open trial for stakeholders and introduction to the technical team.
- UAV, ground and in-machine capture of data using multiple systems.

- Image processing.
- Reporting focusing on systems and outcomes.

Additional Flights

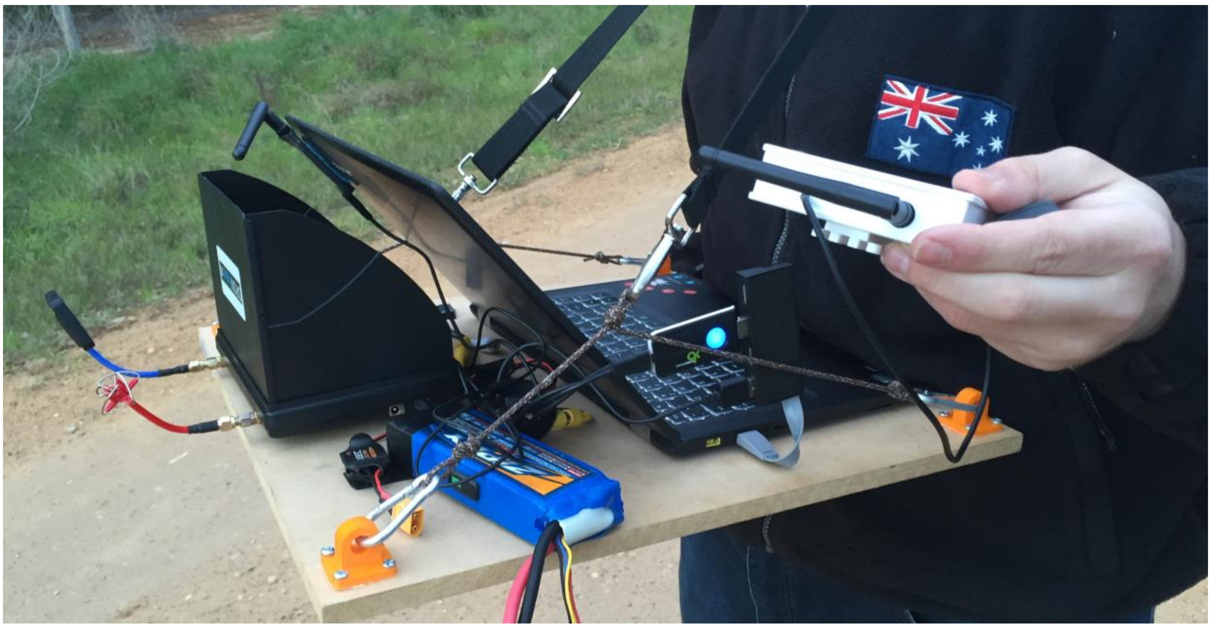
During delivery of the planned major trials, it became necessary to schedule two additional trials. Both of these were to test new equipment operation and collect more data to ensure the planned systems were working and the main trials were successful.

2.1 FLIGHT PREPARATION

The pre-flight preparation included establishing the technical and equipment settings, for the following outputs and considerations:

- Greyscale images (for algorithm detection).
- GPS Coordinates for each captured image – equipment settings required to capture data.
- Isotherm visuals required for industry (can be separate from greyscale images).
- Site safety and equipment requirements – boots, hats, glasses and high visibility.
- Flight approvals
- Flight communications and Trial/On-site trial sheets.
- Weather preparations/permissions.
- Control equipment preparation.

Figure 4: On ground control equipment



2.2 MOBILISATION (ON-SITE)

Mobilisation involved preparing to include minimal on-site stopping and equipment modifications (possible pre-planned flight routes included). The steps included allowing time for equipment switch and issues:

1. Day before koala locating and equipment setup.
2. Induction/pre-flight briefing (trial day).
3. Set up vehicles and flight equipment.
4. Enter route in Mission Planner (rest of data collection).
5. Fly Isotherm setting collection and identify koalas.
6. Collect machine learning grey scale data for later use and processing.

2.3 FLIGHT DETAILS

The flights were semi-automated using autopilot (for safety) with the following flights occurring with the included settings:

- Confirm camera settings (i.e. isotherm or grey scale, etc).
- Define flight parameters (automated flight).
- Flight speed to be selected to meet established test parameters especially overlap.
- No excess images to be captured, no accidental triggered images (i.e., no video or stills if possible during take-off and landing).
- Gimbal 0-degrees
- Early flights (e.g. 6am start to reduce ground heating issues).
- Initial flight with isotherm.
- The camera was then adjusted for Grey scale.

2.4 DATA & PROCESSING (ALGORITHM PROCESSING)

The end goal of algorithm and process development is to take data from the flight SD card and automatically output hotspot (koala) coordinates (on an on-site computer).

Data was sent to the algorithm development team with the following characteristics.

- Co-ordinates (log files) in a .CSV format
- Individual greyscale images
- Some images circled with on-site confirmed koalas so that the team could confirm if the computer correctly identified a koala.
- Any excess images or video edited out before forwarding.

Outputs of the algorithm development team include the located image hotspots with related koala co-ordinates. Kingfisher planned to process the hotspots and coordinates provided by the ACFR using additional software, further refining outputs, to provide an overall summary of koala locations. This summary would remove duplicates and other issues identified in the initial processing.

3. TRIAL RESULTS

There were five trials with various settings and outcomes. Lessons from each trial were captured and used to develop the follow-on testing. The final results ended in the development of a suggested operational regime described later in the report. The general outcome of each stage is described below.

3.1 TRIAL 0

Trial 0 was designed as an equipment and processing trial.

Cameras and Gimbal parts arrived and were tested.

Test data was gathered and sent to AFCR and Imagus Pty Ltd for initial suitability testing. There were no significant lessons from this trial other than that equipment was suitable for use.

3.2 TRIAL 1

Trial 1 was the first field-data collection trial. All equipment was tested, allowing fine-tuning to improve accuracy and reduce processing time.

Some key aspects of the trial were:

- Data collected successfully on June 30, 2016.
- Multiple koalas were located using the UAV-mounted thermal imaging camera.
- Koalas were located using the “isotherm setting” on the FLIR camera.
- The Koalas were visually located from the ground using a GPS and correlated with the UAV data.
- Seven sets of different aerial thermal data with different settings were collected - All data was collected using the isotherm setting on the camera.
- The robotic learning/software group processed the data collected.
- Koalas were also located from a ground-based thermal camera system.
- Data analysis showed that improvements in data collection and processing were required to improve accuracy and processing time.
- The Micasense RedEdge camera mount and an on-the-ground thermal camera system were designed and built using 3-D printing to investigate alternative identification methods. Unfortunately, due to time constraints, the camera was not used and no data was collected.

Figure 5: Isotherm image showing koala hot-spot (centre of red circle)

Although Koalas were located, using the "Isotherm" setting it was discovered that these images were unsuitable for processing through the computer. In the Isotherm mode, the camera records a video which is then subsequently sliced down for further processing. Through this process, the geotagging ability is lost. In addition, the setting forces image scaling in such a way that the scale of temperature is lost. In other words, it seeks the hottest spot then automatically adjusts the settings to wash out a significant portion of the scaling. As a result, the Isotherm setting is unsuitable for computer processing.

This limitation meant the "greyscale" setting was required for the automated 'computer learning' algorithm. In this setting and having the camera combined with a Teax backpack enables individual images to be taken that can be geotagged, further facilitating the post image processing.

It is also noteworthy that the Isotherm setting is suitable for visual identification but the greyscale setting makes it nearly impossible to identify koalas in real time with the human eye.

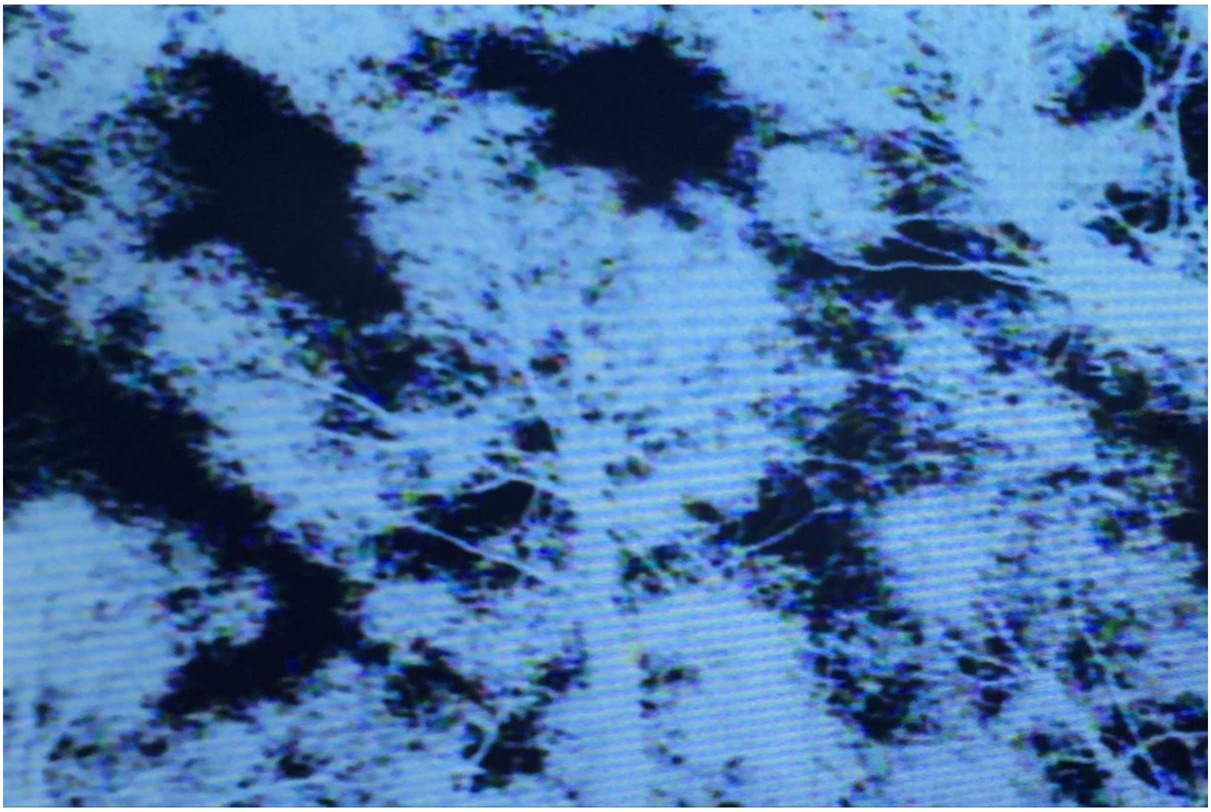
Data in this trial was collected continuously using the video setting which was incompatible for geo-referencing (X and Y coordinates of the video stream).

Figure 6: Greyscale image

Figure 7: The UAV taking off

Although thermal imaging positively detects koalas from the air (UAV) it was found that ground (hand-held) detection was difficult as the images on the FLIR camera became washed out by background heat images.

Figure 8: Upward looking thermal image



As a consequence of the above results the trial equipment was upgraded with the Teax backpack to allow still image capture with geo-referencing.

A flowchart depicting a draft operational system that could be used in the field was produced. This flowchart was refined with follow-on operations and is described further below.

It was also found that the following key aspects needed attention in future trials and equipment refinement:

- Environmental conditions, particularly wind strength, affects UAV operations - approximately 20 knots was a limitation with the expensive equipment chosen (c. $30,000 UAV and camera setups). Alternative cheaper options are available and would need to be investigated for full operations.
- Significant improvement in data collection is required to improve post-processing algorithm performance.
- The main issue in locating koalas with thermal output using the Isotherm setting and the naked eye on a ground-based screen in real time was poor ground to air reception. Any operations will need a clear line of sight.
- An abridged version of Trial 1 (Trial 1B) would be required to collect interim data to assess new equipment and processes before embarking on the next full trial.

3.3 TRIAL 1B

After evaluating Trial 1 and once the Teax backpack was delivered an unplanned trial to confirm operation of the new equipment was undertaken. The trial provided additional data and refinement prior to conducting Trial 2.

The trial confirmed the operation of the equipment and that it was suitable to conduct the following Trial 2.

3.4 TRIAL 2

Trial 2 was conducted with geo-referencing and still capability instead of video capability enabled. Trial 2 data collection was completed successfully on September 7, 2016.

The initial flights were conducted with the isotherm setting on the camera to visually identify koalas as in Trial 1. This also provided a base line for the machine learning team at ACFR.

Subsequent flights were conducted at various heights and overlaps to determine the best flight conditions to conduct data collection. Thee various combination included 50m, 60m and 70m UAV height and 70 per cent, 60 per cent and 50 per cent image overlaps.

Unfortunately, the camera experienced 'false firing' which complicated post processing and geo-referencing. This false firing resulted in two images being taken at the same spot and missed photos and made it extremely difficult to process accurately. In addition the geotagging failed due to an equipment mismatch.

Further equipment refinement was therefore undertaken and included in Trial 3. These refinements included a software upgrade and the need to purchase a specific GPS module for the operational version to improve accuracy and data processing.

The data was sent to the ACFR for further algorithm development. The algorithm processing successfully located the koalas and the algorithm was significantly improved. The following key aspects were identified by the ACFR:

- The robotic learning/software groups received the data collected in Trial 1 and returned a variety of different outcomes.
- Original hotspot detection algorithm returned too many positives, due to background temperature issues. This problem could be fixed using multiple alternative collection settings including setting the gimbal at an offset and was tested in Trial 3.
- ACFR developed an alternative algorithm that detected fewer positives, which included detected ground koalas.
- Of the various settings and test described above it was determined that the lowest height and most overlap significantly improved detection. These settings did not significantly increase the number of photos as the UAV was travelling at 2metres/sec and the programing found it necessary to take an image every 4 secs.

The processing time necessary to process all the images was not prohibitive and within expected time frames.

- While on site, multiple koalas were originally ground validated and subsequently had the same area detected using both algorithms.
- All equipment is working as expected, with the additional setting being located for increased refinement and accuracy.

As a result there were several refinements developed for Trial 3:

- Additional equipment is required to finalise Geo location data. This equipment is already in place but further refinement of the process is required to improve accuracy.
- Future Flights will be conducted at low altitude with 70 per cent overlaps to improve data and algorithm accuracy.
- Additional data sets will be required to operationally develop the detection algorithm.

3.5 TRIAL 3

This was the first trial where industry attended and was used as a system demonstration day.

Figure 9: Industry trial below tree where koala was located by the UAV

Figure 10: UAV located this koala at mid-tree height

Trial 3 was conducted using the following process:

- The Kingfisher team arrived early on site and located Koalas using the Isotherm setting on the Flir Camera.
- The flights were flown low level approx. 60 m with 70 per cent overlap and the gimbal set at 0-degrees.
- Additional flights were conducted with gimbal tilted to 20 per cent to investigate the effect of reducing ground clutter.
- Line of sight was maintained throughout the flight
- Industry arrived on site and the isotherm flights were conducted and koalas were easily located.
- While industry confirmed ground location of koalas, the Kingfisher team changed the equipment to grey scale setting to allow machine learning data to be collected.
- Flights were conducted at the same height and overlap with two gimbal setting as described above.
- Data was subsequently processed.

The trials clearly demonstrated that koalas could be located and machine learning data collated. It also demonstrated that a gimbal angle reduced the background washout problem increasing accuracy.

The trial and equipment was successfully demonstrated to industry.

4. OUTCOMES

4.1 WHAT WE LEARNT AND KEY EQUIPMENT SETTINGS

The trials resulted in several key lessons including the following:

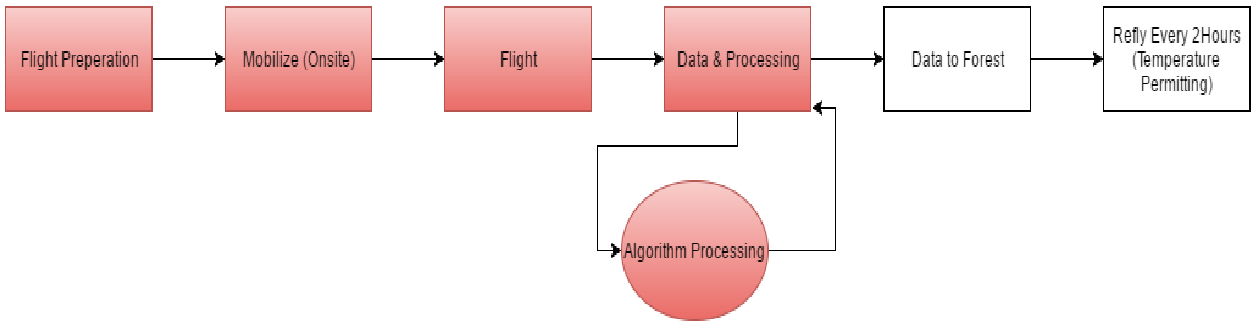
- Koalas can be visually located using the Isotherm setting on the Flir camera.
- Lower altitude improved koala computer algorithm detection. All flights should be conducted between 50 and 60 m
- Increased overlap will also improve detection. All flights should be conducted at 70 per cent or greater overlap.
- Geotagging results require individual image collection and the installation of a Teax matched GPS chip.
- The computer requires grey scale to work effectively.
- On-board processing is possible but requires further development.
- Gimbal Offset of 15 to 20-degrees improves detection by reducing background heat clutter.
- Cheaper operational equipment needs to be identified to reduce the risk of loss. Current trial equipment and significant redundancy which may not be required in full operation.
- Flights should be conducted as early as possible and at first light. If flights are required before first light special operational plans and clearance forms from CASA will be required.
- As the temperature of the day rises, it becomes increasingly difficult to identify koalas so early commencement of operations is essential.
- It was noted that at full operational speed the flight to cover 100m by 150 m of forest would take only 4 to 6 minutes, allowing sufficient time to locate koalas during full-time operation.
- An operational system would require only two personnel in the field familiar with UAV operations therefore providing a cost-effective solution.
- Minimum forest access would be required however line of site would need to be maintained.

4.2 OPERATIONAL AND COMMERCIAL SOLUTION

A possible commercial operational solution was developed. A general daily protocol would be as follows in figure 11:

The process for each step in the protocol is described below.

Figure 11: Flow chart summary



Flight Preparation

Pre-flight preparation involves establishing the technical and equipment settings including:

- Special site considerations (i.e. line of sight)
- Required equipment, serviceability and battery management considerations
- Software considerations
- Site safety and equipment requirements – Boots, Hats, Glasses and High visibility.
- Flight approvals and planning
- Flight communications & Trial/On-site trial sheets
- Weather preparations/permissions.

Mobilisation (On-site)

Essentially mobilisation includes preparing to include minimal on-site stopping and equipment modifications (possible pre-planned flight routes included). The steps of which include (allowing time for equipment switch and issues):

- Induction/pre-flight briefing (the day of)
- Set up vehicles and flight equipment
- Enter route in Mission Planner
- Interaction with onsite forestry personnel.

Flight

The flight will be entirely automated occurring with the included settings:

- Confirm camera settings (i.e. Grey scale, etc).
- Define flight parameters (automated flight). All flights to be conducted between 50 and 60m and with 70 per cent image overlap.

- Flight speed to be selected automatically to meet the parameters below and as established above.
- Early flights (e.g. 6am start, reduce ground heating issues) with CASA approval.
- The first flight will be conducted with the Isotherm setting and 0-degree gimbal angle. All Koalas will be identified visually.
- The camera will then be adjusted for Grey scale and subsequent flights will use machine learning software to identify koalas. Two flights will be run, the first with 0-degree gimbal angle and the second with a 20-degree angle.

Data & Processing (Algorithm Processing)

The machine data software will be processed automatically onboard and the output will be combined post flight with the Isotherm data to generate koala data for the forestry operators.

Re-fly Every Two Hours

After the initial flight there will be targeted subsequent flights assumed to be every two hours. These flights will check on the location of previously located animals and will be completed manually. The UAV will fly straight to GPS coordinate and hover, check for presence on screen, confirm no change, or if the koala has moved, fly a spiral outwards up to a 30 metre radius until the animal is located.

4.3 THE RESULTS FROM ACFR

The ACFR successfully developed an algorithm that can identify koalas with geotagged greyscale images suitable for processing. A summary report is included at Appendix 1.

4.4 OTHER UAV DATA COLLECTION ABILITIES THAT ADD VALUE TO FORESTRY OPERATIONS

Kingfisher also has a multispectral camera that can provide additional useful data which can be collected while scanning for koalas or between missions on other forestry areas.

The widespread availability of low-cost UAVs enables agricultural professionals to cost-effectively gather crop spatial and spectral data (e.g. health information) without waiting for satellite passes or paying the high costs of manned-aircraft flights. Information can be collected at resolutions measured in just cm/inches per pixel. Data captured on a frequent basis enables growers and agronomists to map the health and vigour of the forest today as well as observing how that crop is changing over time.

The advanced data gathering and processing system, coupled with professional analysis tools, provide accurate and repeatable information on the status of a forest. Raw data from the camera is transformed into vegetation index maps using spectral analysis. Powerful analytics provide time-based trends and change maps. Analysis tools such as plant population counts optimise farm management.

The RedEdge™ is an advanced, lightweight, multispectral camera optimised for use in small UAV systems and manned aircraft as well. RedEdge™ provides accurate multi-band data for agricultural remote sensing applications.

RedEdge™ is more than just a camera, sharing more design features with earth-imaging satellites than it does with standard consumer cameras. Industrial imaging sensors provide a high dynamic range in varying lighting conditions while removing artefacts commonly seen in UAV video and imagery. Kingfisher provides a complete imaging, processing and analysis system ready for integration with any platform.

4.5 FUTURE DEVELOPMENT AND RESEARCH

To finalise a commercial solution, the following additional work is required:

- Additional data collection is required to refine algorithm performance.
- It would be necessary to design and install onboard processing to enable real time computer processing.
- A Teax matched GPS chip would need to be purchased and installed.
- A completed system would need final field trials.
- The Red Edge camera would need to be tested to confirm data useability.

Appendix 1 ACFR DRAFT REPORT

1. Automated Koala Detection

This section outlines the outcomes of a preliminary study into automated algorithms for detecting koalas in thermal imagery collected by an unmanned aerial vehicle (UAV). We address this aim by:

- Presenting a background to thermal sensing;
- Describing the approach to koala detection in thermal imagery; and
- Giving an overview of initial results.

2. Background: Thermal Sensing

In this study, thermal imagery is used to detect koalas amongst vegetation. The fundamental principle is that koalas, being warm-blooded animals, will have a higher temperature than any other object in the environment, and can thus be distinguished from the background as a hot-spot in thermal imagery captured by an infrared camera.

Infrared cameras such as the FLIR Tau 2 sensor used in this study measure the infra-red radiation emitted by objects in the environment. The amount of infra-red radiation emitted by an object is related to its temperature; however, this relationship differs for each material (for example, leaves, koalas and soil) based on a property of the material known as its emissivity. Emissivity is a dimensionless number between 0 and 1 that defines how much infrared radiation is emitted at a given temperature. For example, the emissivity of soil can range from 0.4 to 0.98[1], whereas biological materials often have emissivities of 0.9 – 0.97[2].

In typical applications of infrared cameras, the material being imaged (and thus its emissivity) is well known and characterised. In these applications, it is a relatively simple task to calibrate the camera such that the images it collects accurately reports the temperature of the object being imaged. However, in this application, there is a variety of materials being imaged, including trees, soil and koalas. Thus, there is no single emissivity that the camera can be calibrated to. While different pixels of the image may be calibrated differently depending on what is observed in the scene, this calibration requires us to detect the koalas (and trees, soil and any other objects) in the first place and is thus of no use when the application is to detect koalas.

The implication of this observation is that while two pixels of an infrared image collected over a typical scene may have the same intensity (measured infrared radiation), they may be of different temperatures. Consequently, a hotspot in an infrared image may be due to a warm object, such as a koala, that has a relatively low emissivity, or a cooler object, such as soil, that has a higher emissivity. In other words, detecting koalas by finding hotspots in images alone is likely to result in a large number

[1] Sobrino, José A., et al. "Soil emissivity and reflectance spectra measurements." *Applied optics* 48.19 (2009): 3664-3670.
[2] Speakman, J. R., and S. Ward. "Infrared thermography: principles and applications." *ZOOLOGY-JENA-* 101 (1998): 224-232.

of false positive detections, where another object in the environment is mistaken for a koala. Further, there may also be false negatives, where a koala is not detected. An example of false positive detections is shown in Figure 13. A true koala detection that has the same intensity (infrared radiation as measured by the camera) is shown in Figure 12 for comparison.

Figure 12: Example of a true koala detection

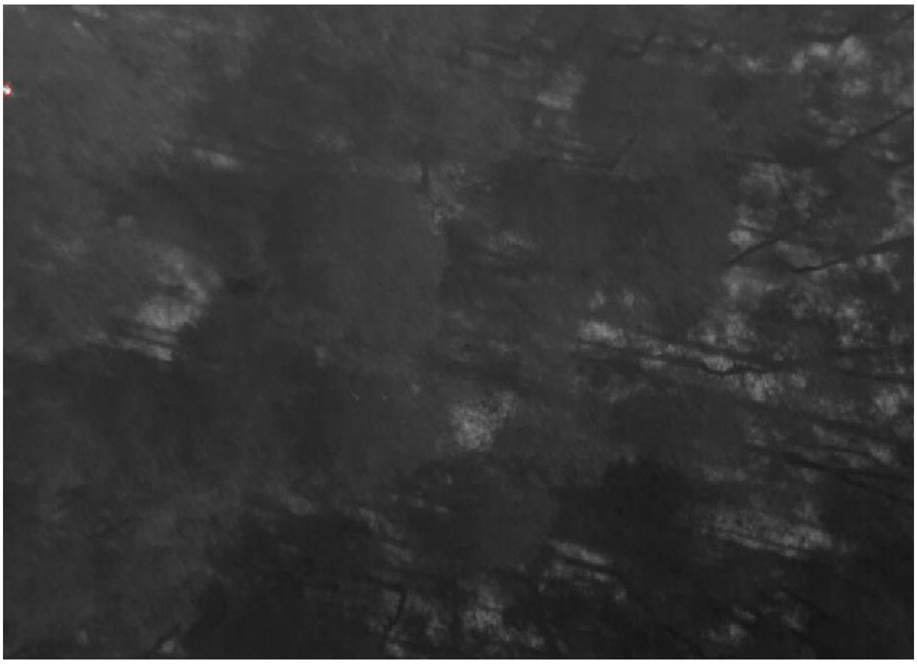
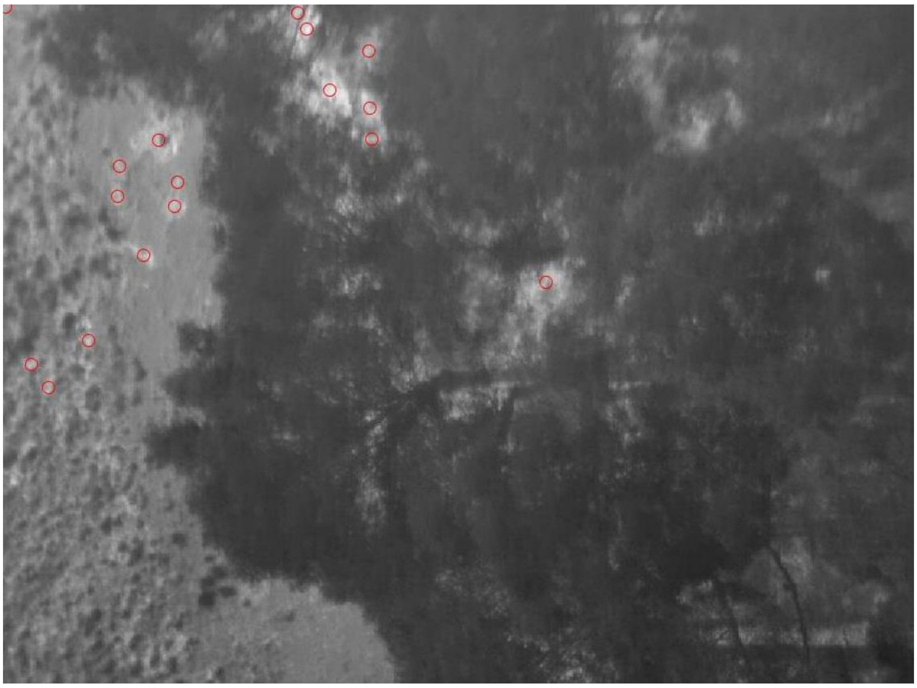


Figure 13: Example of multiple false positive detections. These detections have the same intensity (infrared radiation) as the koala detection shown above

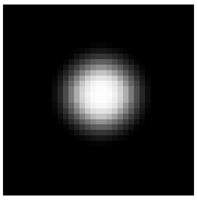


3. Approach

Given the limitation of using hotspot detection alone for detecting koalas, we approach the problem by applying domain knowledge and observations from the data collected. We noted that koalas are typically present in trees. Further, we noted that trees typically have low intensities (infrared radiation) in the imagery. This is in contrast with soil, which can contain hotspots that appear similar to koalas. Thus, the intuition behind our approach is to look for a bright "blob" that is approximately circular, has a certain size, and is surrounded by darker (emits lower levels of infrared radiation) objects.

The technique used in this study is *template matching*. Template matching is a well-established technique in computer vision for detecting objects. In this technique, a template is convolved (compared) against patches of an image. The template represents the object that is being detected. In this case, the template comprises a white circular blob surrounded by a black background, as shown in Figure 14. A similarity score is given for each patch in the image; detections occur when this similarity score exceeds a tuned threshold. To account for variations in exposure in each image, the dynamic range (difference between the brightest and dullest pixel) was normalised between 0 and 1 for both the template and each patch.

Figure 14: Template used for this study



4. Results

The template-matching based approach was tested on 196 images collected over 9 flights flown at various altitudes. Each image was visually inspected to determine whether there was a koala or not. The template-matching approach resulted in detections in 17 images, of which 10 were true detections and 7 were false positives. An example of a koala detection is shown in Figure 15.

The manual inspection of all 196 images found 11 images of koalas, meaning that the proposed approach resulted in only one false negative detection. This false negative, shown in **Error! Reference source not found.**, occurred as the koala was on the edge of the frame.

Examples of false positive detections are shown in Figure 16. It can be seen that the false positive detections look like koalas when viewed in isolation; only contextual cues shown that they are in fact not koalas.

Figure 15: Example of a koala detection

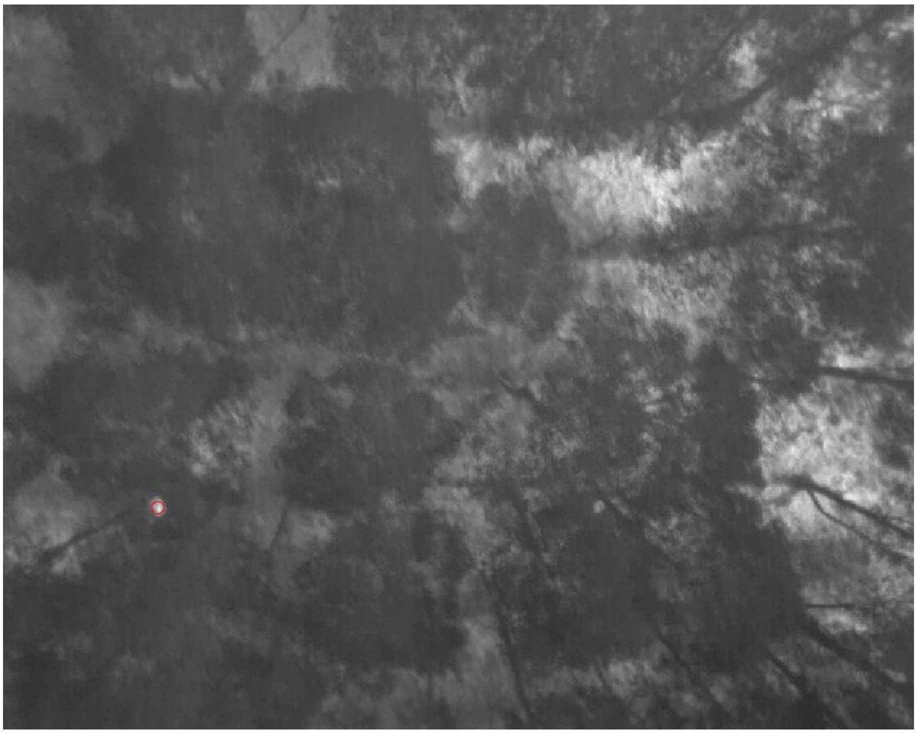
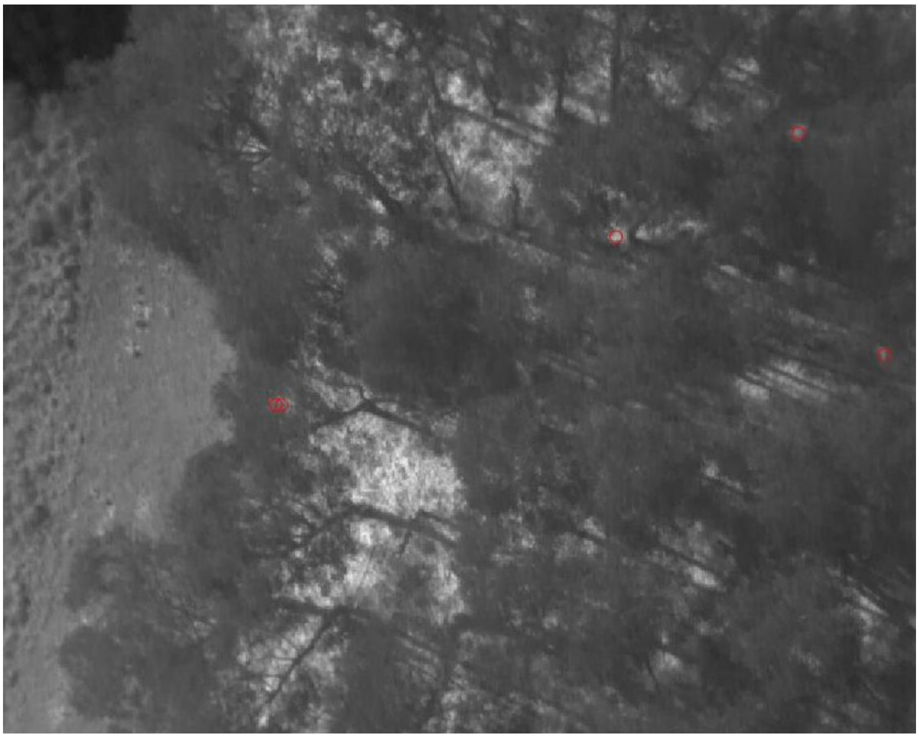


Figure 16: Examples of false positive detections



Disclaimer

Kingfisher Data Services (Kingfisher) issues this report to the Forestry Consortium who co-funded the Forest and Wood Products Australia (FWPA) Koala Location trials. The report is for the consortium's use. No responsibility is accepted for any other use.

The report provides a detailed description of a trial process along with subsequent results and findings.

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Kingfisher Data Services Pty. Ltd.

Trevor Bourne

Director

27 October 2016