THERMAL INFRARED CAMERAS AND DRONES: A MATCH MADE IN HEAVEN FOR COST-EFFECTIVE GEOTHERMAL EXPLORATION, MONITORING AND DEVELOPMENT

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1. ABSTRACT

Drones are now routinely used for collecting aerial imagery and creating digital elevation models (DEM). Lightweight thermal sensors provide another payload option for generation of very high resolution aerial thermal orthophotos. This technology allows for the rapid, safe and cost-effective survey of thermal areas, often present in inaccessible or dangerous terrain. Here we present results from recent surveying at the Tauhara thermal area, New Zealand. Our results show that thermal imagery collected by drones has the potential to become a key tool in geothermal exploration, including geological, geochemical and geophysical surveys, environmental baseline and monitoring studies, geotechnical studies and civil works.

2. 1. INTRODUCTION

Photogrammetry is a technology that allows measurements to be made from photographs and, for the reconstruction of three dimensional information (i.e. Digital Elevation Models), from a mosaic of overlapping, two dimensional photographs (Li et al., 2010).

Although photogrammetry is not a new technology, recent advances in drones equipped with global positioning systems (GPS) and digital cameras have reduced the cost of collecting imagery. Modern desktop and cloud computing power allows for routine post processing of large numbers of individual image photos. The individual photos are combined into aerial orthophotos and Digital Elevation Models (DEM) of comparable quality (<0.1m) to airborne LiDAR (Harwin & Lucieer, 2012; Fonstad et al., 2013).

Lightweight thermal sensors provide another payload option for generation of very high resolution aerial thermal orthophotos. This technology promises to allow the rapid, safe and cost-effective survey of thermal areas, often present in inaccessible or dangerous terrain.

In this study we provide preliminary results from a thermal infrared survey of part of the Tauhara thermal area, New Zealand. The survey was undertaken using a UAV equipped with a point and shoot digital camera for normal visible images (RGB), and a thermal infrared camera.

2. METHODS

2.1 Field Methods

Imagery was collected using a modified DJI Phantom 2 Vision+ quadcopter (Figure 1). The quadcopter was modified by the replacement of the stock camera with an ICI 640x480 uncooled thermal sensor (spectral response 7-14µm) with automated image capture. A Canon S100 point and shoot camera was fitted for normal visible (RGB) and DEM outputs (Harvey et al., 2014).

Figure 1: DJI Phantom quadcopter modified with ICI thermal camera

An appropriate flight plan was determined using DJI Ground Station® software. The flight plan was then uploaded to the quadcopter's flight controller using the DJI Vision App. Accordingly, both in-flight navigation and image capture were autonomous.

Two flights were conducted for the thermal imaging, each of approximately 10 minutes duration giving a total flight time of about 20 minutes. Flight altitude was 30m (relative to the launch point), with a ground speed of 2 m/s.

Three flights were conducted for the RGB imaging, each of approximately 12 minutes duration giving a total flight time of about 40 minutes. A detailed discussion of RGB mapping is provided in Harvey et al. (2014).

Fight conditions were calm with a maximum wind speed of ~5 km/hr. Although clear with good visibility, the flight was conducted with the sun at a relatively low angle with respect to the horizon (late August morning in the Southern Hemisphere).

2.2 Image Processing

604 geo-tagged RGB images were processed using Pix4d® and provided an RGB orthomosaic a digital elevation model of an approximately ~0.9 km^2 area, including the smaller thermal study area.

The smaller thermal study area (magenta box in Figure 2) was covered by 373 overlapping thermal images. The images were processed using Pix4d®, commercial photogrammetry software (Figure 4). Images were geo-tagged automatically during flight and this provided georeferencing for the resulting 3D model and orthophoto.

The ground resolution and position error of all outputs was determined automatically by Pix4d®.

Figure 2: Georeferenced RGB orthomosaic showing thermal infrared study area (magenta square).

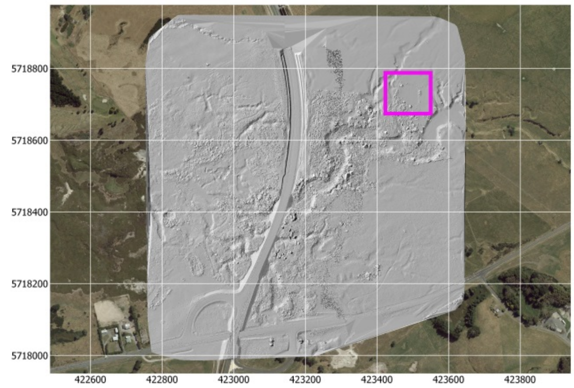

Figure 3: Georeferenced digital elevation model showing thermal infrared study area (magenta square).

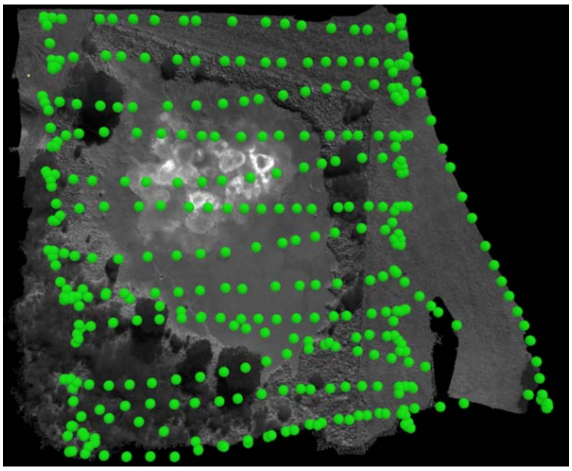

Figure 4: Thermal camera locations (area inside magenta square in Figures 2 and 3).

2. RESULTS

RGB image (normal visible image) processing provided a georeferenced orthophoto (Figure 2) and Digital Surface Model (DSM)(Figure 3) with 0.9 km^2 coverage area. Ground resolution was 4cm (pixel size). The thermal survey area (see magenta box in Figure 2 and 3) has been expanded to show the quality of the RGB orthophoto and DEM (Figure 5 & 6).

Thermal image processing provided a georeferenced thermal orthophoto (Figure 7) and 3D digital model (Figure 8) with 0.01 km^2 coverage area. Ground resolution was 3cm (pixel size). Positional error was 4.3m (x), 5.0m (y) and 8.4m (z).

All map coordinates are UTM WGS84 (Figures 2-7)**.**

4. DISCUSSION

As with previously reported results (Harvey et al., 2014), the RGB derived orthophoto and Digital Elevation Model have resolution comparable to LiDAR imagery (4 cm).

Thermal imagery also provided a high resolution orthomosaic and digital model (3 cm pixel size). The average positional error (~5m in the x and y plane) is a consequence of the accuracy of the on-board GPS (+/- 5m). Accordingly, major improvements in positional error (<0.1m) are expected if accurate ground control points are utilised, as have been reported elsewhere (Harwin & Lucieer, 2012; Harvey et al., 2014).

The thermal orthophoto mosaic (and 3D model) is produced from a set of hundreds of individual images. Both 16 and 32 bit pixel response raw data, and calibrated temperature data (manufacturers claim ± 1ºC) can be extracted for every pixel in an image, allowing for quantitative analysis of extremely large datasets (each image contains 640x480 pixels).

5. CONCLUSION

Our study has demonstrated a low cost approach to the production of georeferenced Digital Elevation Models (DEM) and orthophotos from normal visible (RGB) images captured by drone. The ground resolution of our DEMs and orthophotos are comparable to commercially produced LiDAR and aerial imagery obtained from manned aircraft.

This technology allows for the rapid, safe and cost-effective survey of thermal areas, often present in inaccessible or dangerous terrain. Thermal and RGB imagery collected by drones has the potential to become a key tool in the early phases of geothermal exploration and development including geological, geochemical and geophysical surveys, environmental baseline and monitoring studies, geotechnical studies and civil works.

Future work will include testing the accuracy of the factory calibrated temperature data, providing temperature maps, and integrated heat flow estimates for thermal areas.

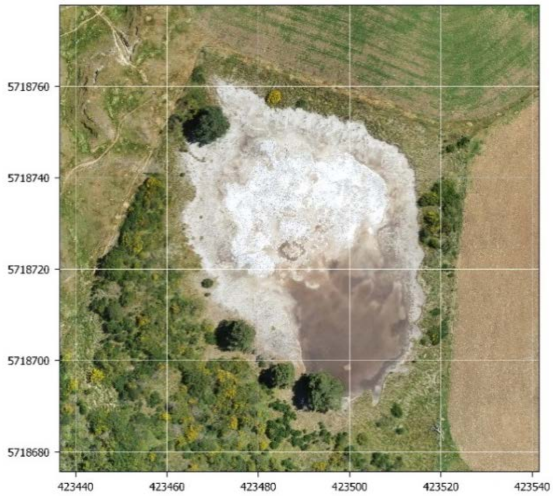

Figure 5: Georeferenced RGB orthomosaic

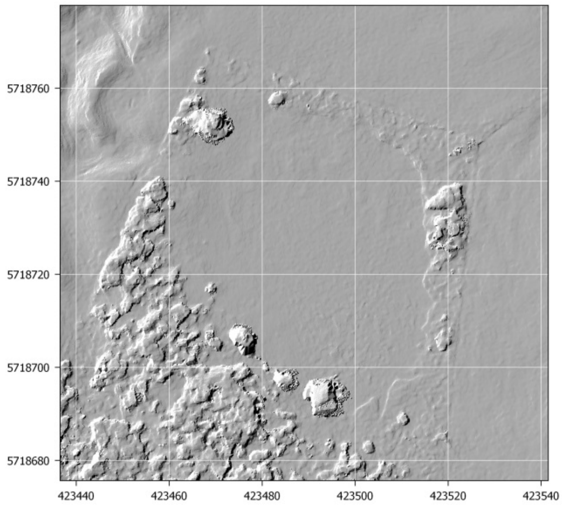

Figure 6: Georeferenced digital elevation model (DEM)

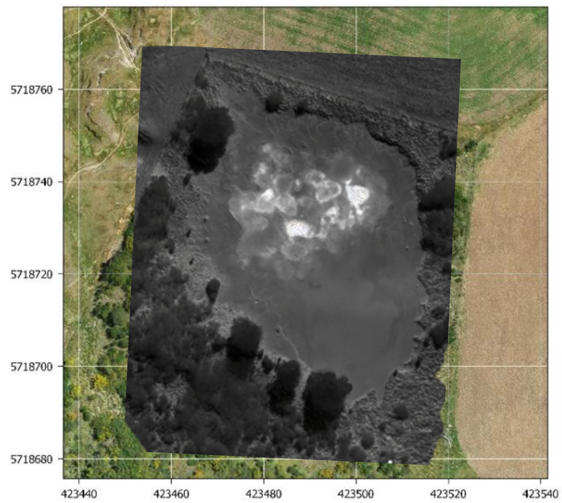

Figure 7: Thermal orthomosaic. Lighter shading indicates higher temperature.

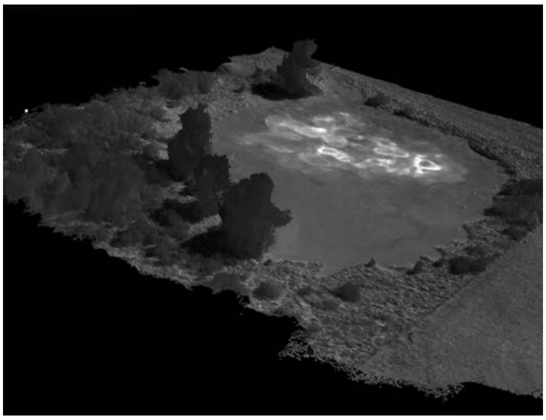

Figure 8: Georeferenced thermal 3D model (triangular mesh). Same area as Figures 4 – 7, and magenta square in Figures 2 and 3.

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