Hyperspectral imaging from unmanned aircraft systems (UAS)–Sensor integration and geometric processing workflows for pushbroom and snapshot sensors

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Abstract:
In this study, we integrated and operated two hyperspectral sensor systems on a small (10 – 15 kg) multi-rotor unmanned aircraft system (UAS) for environmental and agricultural remote sensing. We integrated a Headwall Photonics micro-Hyperspec pushbroom sensor with 324 spectral bands (4 – 5 nm FWHM) in the VNIR spectral range. The sensor was mounted on a gimbal to stabilise the aircraft dynamics, and tightly coupled with a dual frequency global navigation satellite system (GNSS) receiver, an inertial measurement unit (IMU), and machine vision camera to accurately orthorectify the hyperspectral image strips. We describe the technical challenges in integration and coupling of multi sensors, and we show the radiometric/spectral calibration and geometric processing workflows.
In addition, we describe the integration of a 25-band hyperspectral snapshot sensor (PhotonFocus camera with IMEC 600 – 875 nm 5x5 mosaic chip) on a multi-rotor UAS. The sensor was also integrated with a dual frequency GNSS receiver for accurate time synchronisation and geolocation. We describe the sensor calibration workflow, including dark current and flat field characterisation. A structure-from-motion (SfM) workflow was implemented to derive hyperspectral 3D point clouds and orthomosaics from overlapping frames. On-board GNSS coordinates for each hyperspectral frame assisted in the SfM process, and allowed for accurate direct georeferencing (<10 cm absolute accuracy). We present the processing workflow to generate seamless hyperspectral orthomosaics from hundreds of raw images. Spectral reference panels and in-field spectral measurements were used to calibrate and validate the spectral signatures.
The application of the two hyperspectral UAS sensors is demonstrated in three real-world experiments. First, we deployed the hyperspectral pushbroom sensor in Antarctica to quantify biophysical and biochemical properties of Antarctic moss beds. Second, the hyperspectral snapshot sensor was deployed over an agricultural opium poppy crop in Tasmania, Australia to quantify crop health. Third, both sensors were deployed over a native grassland site in Tasmania and a rangeland site in central Australia for identifying of grassland species.
We present our detailed experiences of sensor integration, operation, calibration, validation, and preliminary results from three real-world case studies.

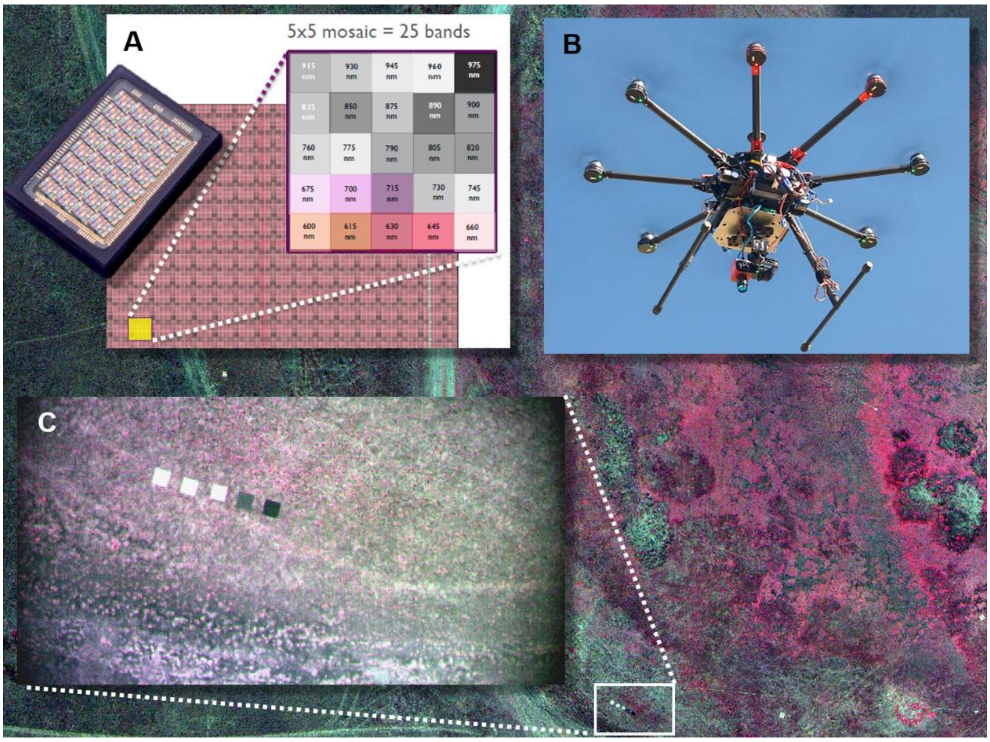

Figure 1. New hyperspectral snapshot imaging sensor with 25 spectral bands based on state-of-the-art CMOS technology enables miniaturisation of hyperspectral cameras; B: multi-rotor RPAS with integrated hyperspectral sensor for remote sensing applications developed by the UTAS TerraLuma group; C: example of single RPAS image of spectral calibration panels (40×40 cm) illustrating the impact of lens vignetting as a darkening in the image corners; the background image shows a 7 cm resolution hyperspectral mosaic of a ~1 ha area of native grassland in Tasmania.

References:

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